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LESSONS,

ASTRONOMICAL AND PHILOSOPHICAL,

FOR THE
AMUSEMENT AND INSTRUCTION
OF
BRITISH YOUTH:
BEING
AN ATTEMPT TO EXPLAIN AND ACCOUNT FOR
THE MOST USUAL
APPEARANCES IN NATURE,
IN A FAMILIAR MANNER
FROM ESTABLISHED PRINCIPLES.
THE WHOLE INTERSPERSED WITH
MORAL REFLECTIONS.

BY OLINTHUS GREGORY.

> ————————— The glittering stars,
> By the deep ear of meditation heard,
> Still in their midnight watches sing of HIM.
> He nods a calm. The tempests blow his wrath,
> The thunder is his voice; and the red flash
> His speedy sword of justice. At his touch
> The mountains flame. He shakes the solid earth,
> And rocks the nations. Nor in these alone,
> In *every common instance* GOD is seen.
>
> THOMSON.

THE SECOND EDITION,
MUCH ENLARGED AND IMPROVED.

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1799.

BRITISH MUSEUM
14 JUL 51

TO

THE RIGHT HONOURABLE

JOHN JOSHUA PROBY,

EARL CARYSFORT,

EVER ZEALOUS IN THE PROMOTION AND ENCOURAGEMENT

OF USEFUL WORKS;

UNDER WHOSE PATRONAGE

THE FORMER EDITION OF THIS PERFORMANCE

MET WITH

SO FAVOURABLE A RECEPTION:

THE PRESENT IMPROVED EDITION

IS RESPECTFULLY DEDICATED

BY

HIS LORDSHIP'S

MOST OBEDIENT, AND MOST OBLIGED,

HUMBLE SERVANT,

OLINTHUS GREGORY.

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14 JU 61

PREFACE.

IT has been for a considerable time allowed by the majority of intelligent persons, that amongst a variety of studies there are none of greater utility, or that afford more real pleasure to a rational mind, than those on *Philosophical Subjects*. On mature deliberation it may be concluded, that this does not so much arise from any intrinsic value of PHILOSOPHY, solely considered, as from the peculiar use to which it may be applied, and without which it hardly merits the name it has obtained: and this is no other, than regulating by it our observations upon the numerous objects of the creation, whereby we may correct any erroneous notions which we may have hitherto encouraged, either concerning them, or the

OMNIPOTENT POWER by whose *Will* they were formed.

When it is considered how liable all our senses are to deception, and what wrong ideas are generally formed of the different parts of the universe from mere cursory observation, the absolute necessity of the dissemination of true philosophical principles will the more obviously appear. And if the rudeness and imbecility of the human mind in an uncultivated state of nature be taken into the consideration, it will be the more readily admitted, that every attempt to extend the sphere of human knowledge is laudable in its nature; and, if it be found to answer the intention, is deserving of encouragement.

Being duly impressed with the force of these reflections, and also recollecting that it is the indispensable duty of every member of society, to render himself as serviceable to his fellow-creatures as his abilities will allow, I was induced to apply my leisure hours to the execution of a performance which might in some measure tend to the instruction of the *Youth of Great Britain*. And as my principal design was to lay before

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fore them some pages of the *Volume of Nature*, I judged that if this could be performed in such a manner as to be also a source of amusement, it would probably meet with a more welcome reception, and consequently have the better effect.

Pursuant to these ideas, I have divided the following work into easy leſſons of various lengths, as the nature of the respective subjects would admit; and have interspersed them with moral reflections, in prose and verse, in order to alleviate the mind of the student, and to lead him by imperceptible degrees, to reflect seriously on the several objects around him. To the honour of our British Poets, I was seldom at a loss for an Extract suitable to my purpose; and if my acquaintance with their works had been more extensive, I believe there would have been no occasion for those two or three little pieces, which make so dim an appearance in such brilliant company.

These Lessons may with propriety be introduced into Schools, to be read before the master in greater or less proportions, as may be thought most proper: in which case they will answer a double purpose,—improving the Pupil in the Art of Reading, and enlarging the bounds of his understanding. That they might be as much as possible subservient to the former, without raising an impediment in the way of the latter, reflections attendant on the several subjects are the more frequently introduced.

To some persons it may perhaps appear neceſſary that I should have given an explanation of all the technical terms which are found in the following pages: for instance, such as *centre*, or *center*, *diaphanous*, *equinox*, *focus*, *glands*, *lacteal*, *periſtaltic*, *&c.* Here I would observe, that I have not neglected such explanation where it could be done without leading me too circuitous a course; and even where it is otherwise, the omission will not afford an objection of great weight; for there is scarcely a Dictionary in which the requisite information may not be met with. Perhaps in schools this may be productive of some advantage, as it may lead to enquiry; but that this may have the better effect, it may be remarked, that the preceptor does not properly acquit himself in his duty towards his pupils, who does not indulge them in the liberty of asking every question, the solution of which may have a tendency to encrease their fund of learning. Masters by acting thus, would undoubtedly be able to judge in what respects their scholars were most deficient; and could, of course, supply those deficiencies from their own knowledge, or from those helps which it may naturally be supposed they have at hand.

In the composition of these Lessons, I have not scrupled to make a free use of the Works of several of the most esteemed Authors on Astronomy and Philosophy; and if I have not always acknowledged where the obligation lay, I may observe that such alterations were made, or the extracts taken in so detached a manner, as rendered it nearly, if not absolutely impossible. When we remember that the improvements in these sciences were gradual and not effected by one man, or by one age; it must be allowed that every production (except those which boast of new inventions and discoveries) must be principally a compilation; and the chief merit to which the person who undertakes it can aspire, is that of arranging the materials before him in a manner more suitable to his purpose, and making such reflections as may be best adapted to the subject.

I am conscious, that in the present undertaking many imperfections will be met with: however, such as it is, I present it with chearfulness to the public view; and if it meet with a favourable reception from the candid and ingenuous, I shall have but little to fear from the severe critic. Literary fame I want not to acquire: Zeal for the welfare of the British youth was the only motive which urged me to this performance; and if it prove to be of service to them, I shall think myself amply rewarded. As to the numerous defects, I must sue for indulgence by observing, that I am yet but a young man; and am willing to hope that if health and leisure should permit, I may at some future period produce something more worthy of public favour. Yet, as I am desirous to make this Work as correct and useful as possible, I cannot

annot but add, that those who will be so bliging as to furnish me with hints for its nprovement, will confer a lasting obligaion upon me, and shall receive my grateful cknowledgments.

O. G. GREGORY.

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ADVERTISEMENT.

GRATITUDE for the favourable recepion which the first edition of these LESSONS as experienced, has induced the Author to ive them a careful revisal, in order that his New Edition may be found less unworhy of public favour. In this revisal he has een assisted by the polite suggestions of ome of the Reviewers, (for whose testimoials in favour of his performance he feels eculiarly obliged,) and by many useful ints which have been communicated to im in letters from several of his literary riends; to whom he cannot but acknowledge is obligations, and whose names would reflect onour upon his work, if he were permitted o mention them. He is in a particular maner indebted to a Nobleman of distinguished worth and abilities, for condescending to point out several alterations and emendations, all of which were of so much importance, that his lordship will find they have been universally attended to. The Author has taken care to incorporate into this Edition, all those improvements and discoveries that have been made since the first Edition was published, and that appeared to have any connection with the subjects on which he has treated. Besides the numerous alterations, which are to be met with in almost every Lesson, he has added Three New Lessons,—one on *Electricity*, one on *Fountains* or *Springs*, and one on *Plants* and *Vegetation.* He humbly hopes that these corrections and additions, will ensure to him a continuation of that encouragement, with which he has been already honoured by an indulgent public.

Cambridge,
May 20th, 1799.

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LESSON

LESSON I.

INTRODUCTION.

——— Every object of creation
Can furnish hints to contemplation. GAY.

AS you, my dear young friends, have now arrived t a period of life, in which the mental faculties are apidly encreasing in vigour, you will perceive an nquisitive curiosity, which has long remained dormant in your minds, hastily bursting forth; it will e of the utmost importance to your happiness, both resent and future, that you be careful in directing his innate principle into its proper course.

Ever since you have been possessed of the power f reasoning, you cannot but have observed with onder and admiration, the sun shining with astonishing splendour, dispensing light and heat around; —the moon, with majesty serene, gliding along the rched heavens, scattering her gentle rays, in the bsence of the glittering luminary of day;—and the pacious canopy bespangled with numerous stars, like winkling flames, adding to the beauty of the scene. You must have observed, with awful astonishment, he forked lightning in vivid motion glancing through the wide expanse; and have heard, with fear and anxiety, the tremendous thunder, shaking the firmest buildings with its pealing crash. When you reflect upon these and other appearances in nature, what impressions do you feel? You who have considered these things attentively, will ingenuously confess, that you are thereby led to conceive that there must be some *first cause* which produced, governs, and regulates the whole. The most cursory observation will have induced you to entertain an high opinion of the wisdom, power and goodness of the ALMIGHTY DESIGNER; but I can assure you, my young friends, that the more you reflect upon th universe, in the display of the wonders and beautie of it, and the better you are acquainted with it, s much the more will be increased your reverenc and love of the *Governour of all.*

> Nature is but a name for an effect
> Whose cause is God.
>
> COWPER.

The impressions we receive from the contemplation of the works of nature, must necessarily b connected with that beautiful chain of reasoning which brings us to a knowledge of the Deity him self; nor can the human mind enjoy more intellec tual happiness, than from the assurance, that ther is a powerful and benevolent Being, who not onl regulates the system of worlds, but extends his p ternal care to the meanest of his creatures.

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It is a melancholy consideration that too many young people, instead of being zealous of acquiring real and useful knowledge, suffer a kind of torpor to dwell upon their minds, and give way to such supineness, as may, if they be not quickly roused from their lethargy, be attended with fatal consequences. If any such persons should peruse these Lessons, let me exhort them to shake off their carelessness, and endeavour to furnish their minds, ere it be too late, with a true knowledge of the works and wonders of the creation: be assured that such conduct will produce the happiest effects; for philosophical contemplations will form the safest bulwark against the insidious attacks of Atheists; because the principal intention of such enquiries is, from a consideration of the effects produced, to correct our ideas with respect to the great first cause; or as the Poet has expressed it,

To look through Nature up to NATURE's GOD. POPE.

In these Lessons it shall therefore be my province to explain to you, in a concise, and familar manner, some of the wonders of the universe: I will first lead you to take a survey of the heavenly bodies; and afterwards consider some of those objects and some of those appearances of nature which relate to the earth we inhabit: thus shall we

——See thro' this vaſt extended Theatre
Of skill divine, what shining marks appear!

Creating power is all around expreſt,
The God diſcover'd, and his care confeſt;
Nature's high birth, her heav'nly beauties ſhew,
By every feature we the parent know.
Th' expanded ſpheres, amazing to the ſight,
Magnificent with ſtars, and globes of light;
The glorious orbs which heav'ns bright hoſt compoſe,
Th' impriſon'd ſea, reſiſtleſs ebbs and flows;
The fluctuating fields of liquid air,
With all the curious meteors hov'ring there,
And the wide regions of the land proclaim,
The POW'R DIVINE that rais'd the mighty frame.

BLACKMORE.

LESSON II.

VIEW OF THE HEAVENS.

Heaven
Is as the book of GOD before thee set
Wherein to read his wond'rous works. MILTON.

The heav'ns declare the glory of GOD. DAVID.

AGREEABLY to my plan I shall now endeavour, in the first place, to describe to you the nature, size and motion of the principal heavenly bodies; the beauty and variety of which, have no doubt often filled you with astonishment: following the advice of Ovid,

> " We tho' from heaven remote, to heaven will move
> " With strength of mind, and tread th' abyss above:
> " And penetrate with an interiour light;
> " Those upper depths, which nature hid from sight.
> " Pleas'd we will be to walk along the sphere
> " Of shining stars, and travel thro' the year."

The science which teaches the knowledge of the celestial bodies, their magnitudes, motions, distances, periods, eclipses, order, &c. is called **ASTRONOMY**: the study of this has been applied to with avidity in ll ages, and it has now arrived at a tolerable degree of accuracy. The hypotheses which have been invented by astronomers at different times and in different countries, are numerous, and the greater part of them are too futile in their nature to deserve a particular account: the only one which agrees with all the phænomena is that which was first invented by *Pythagoras* (who was born 577 years before Christ) and taught in Greece and Italy; but this was soon buried in oblivion, and was set aside from the time of Ptolemy, until it was restored about the year 1507, by *Nicholas Copernicus;* at length the indefatigable researches of SIR ISAAC NEWTON have fixed it upon too firm a basis to be easily overthrown; it is now generally acceded to by Astronomers, and is by way of distinction called the *Newtonian system*; an account of which I shall now proceed to lay before you.

When we take a view of the heavenly bodies, our attention is first attracted by the *sun* and *moon*, which are distinctly named *luminaries*; the other beautiful spangles in the glorious canopy are called *stars*, and of these a distinction is made into *planets*, or *wandering stars*, and *fixed stars*. The planets, of which the earth we inhabit is one, move in regular and uninterrupted order around the sun; some of these planets have attendants, usually called *satellites*, moving around them. Sometimes there are other stars seen, with blazing tails issuing from them; these pursue very eccentric irregular courses, and are re called *comets*. The planets[*] themselves are requently called *primaries*, and their satellites *seondaries*. There are two methods of discovering vhich are planets, and which are fixed stars: every ixed star *twinkles*, but a planet does not; for the tars are to appearance only lucid points, and thereore any opaque particle floating in the air, is suficient to cause a momentary eclipse of them [†]; but he planets though smaller, suffer very little apparent liminution; but the proper criterion is this, the planets are always in motion from one part of the neavens to the other, whereas the other stars keep constantly the same distance from each other.

---

[*] Correctly speaking, the Satellites are Planets, as well as hose round which they revolve: for *Planet*, is a Greek word, ignifying any thing that wanders. Agreeably to this acceptation, he Sun itself is a Planet; as it, like the others, has a two-fold motion. And indeed, to complete the similarity, Dr. Herschel has (in a paper which will be presently more largely spoken of) sserted that his body is opaque, and that it is diversified with hills and vallies.

[†] Although the above is the generally adopted method of explaining the twinkling of the fixed stars, yet it is now thought to be inaccurate. Mr. *Michell* justly observes (in the "Philosophical Transactions,") that no object can hide a star from us, that is not large enough to exceed the apparent diameter of the tar, by the diameter of the pupil of the eye; nay, it must be arge enough to hide the star from both eyes at the same time.

Perhaps the principal cause of this twinkling, is the unequal efraction of light, in consequence of inequalities and undulations n the atmosphere.

The names of the planets, beginning with that nearest the sun, are as follow: *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, *Saturn*, and *Georgium Sidus*, or *Herschel*. These are all that are yet discovered, though there very probably may be more: after describing to you the sun, I shall proceed to the rest in their order.

Lesson 3d

LESSO

LESSON III.

ON THE SUN.

——Hail sacred source of inexhausted light!
Prodigious instance of creating might!
His distance man's imagination foils;
Numbers will scarce avail to count the miles.
His globous body how immensely great!
How fierce his burnings! how intense his heat!
As swift as thought he darts his radiance round
To distant worlds his system's utmost bound:
Of all the planets the directing soul,
That heightens and invigorates the whole.

BROWN.

OFTEN as you have beheld the mid-day sun shining in all his grandeur, disseminating his refulgent beams around; and often as you have felt the efficacy of his all-genial heat, you may never have entertained an idea of his vast size. When you are informed of the dimensions of this grand dispenser of light and heat, and when you come to be acquainted with some of the laws by which he is governed, you will consider it as one of the many irrefragible proofs, that the universe could not (as atheists assert) be jumbled together by chance; but that the whole must have been formed by an all-wise, all-powerful, and adorable Creator!

The sun is a body very nearly in the form of that solid which is by mathematicians called a sphere or globe, and the observations of astronomers have proved beyond a doubt, that its axis is nearly 883,210 miles, its circumference 2,774,692 miles, and its solidity in cubic miles 360,737,732,256,524,299: viz, three hundred and sixty thousand, seven hundred and thirty-seven billions, seven hundred and thirty-two thousand, two hundred and fifty-six millions, five hundred and twenty-four thousand, two hundred and ninety-nine: a number, almost surpassing the powers of imagination!

From a cursory observation you would perhaps be led to imagine that the sun moves round the earth once in twenty-four hours; but this is not the case. The sun has two motions, the one is a periodical motion, in an elliptical or very nearly a circular direction, round the common center of all the planetary motions; as this common centre is found to be always exceedingly near the sun, and most commonly within it, I shall henceforward suppose this luminary to be the center of the planetary system, for in such a supposition we shall not fall into any material error. The other motion is a revolution upon its axis which is completed in about twenty-six days, as appears obviously by paying attention to the *maculæ* and *faculæ*, or spots upon his surface.

The sun was supposed, by many of the antients, to be the clearest image of his Maker, "without "spot, or wrinkle, or any such thing." To such a degree a degree had this prejudice arisen, that when *Galileo* discovered several dark spots on the surface of the sun, and mentioned his discovery to another philosopher, he was told that the thing was utterly impossible, and that there must be some defect either in his glasses or his eyes: it was added also, as another proof of the asserter's candour and penetration, that as such a circumstance was not noticed by Aristotle, the pretended discovery could be nothing less than presumption or deception. However, that there are spots on the sun, has since been indisputably confirmed, and is now universally admitted. Of these spots, the dark ones are called *maculæ*, to distinguish them from the others, which are of a brighter appearance than the rest of the sun's surface, and which have obtained the name of *faculæ*

Concerning the nature of these spots, there have been various opinions entertained by different persons. Some have supposed maculæ to be large portions of opaque matter moving up and down in the fiery fluid, of which the sun was thought to be composed or surrounded, revolving near its surface, and sometimes beyond it. Others have taken them for the smoke of volcanoes in the sun, or the scum floating upon a huge ocean of fluid matter. Faculæ, on the contrary, have been called clouds of light, and luminous vapours; and, because maculæ have been sometimes observed to change into faculæ, it has been conjectured, that the latter were the bright flames of volcanoes rapidly blazing out, after the dark smoky matter, which produced the maculæ, became dissipated by combustion. These are the opinions that have been commonly held on the subject; but it does not appear to have been considered with much attention until very lately. The discoveries and observations of Dr. *Herschel*, have in a great measure supplied the defect, and afforded ample materials for forming a rational and plausible theory to explain and elucidate the appearances we are now treating upon.

This ingenious astronomer has given very forcible reasons for concluding, that the opinion commonly received, that the sun is a body of real fire, is futile and erroneous. He supposes, on the contrary, that it is an opaque body, surrounded by an atmosphere of a phosphoric nature, composed of various transparent and elastic fluids, by the decomposition of which, light is produced, and lucid appearances formed of different degrees and intensity. The doctor even goes so far as to assert, with much probability, that the sun is in reality an inhabitable world; but this assertion has no connection with our present enquiry, which we must confine, for the present, to maculæ and faculæ. Admitting, therefore, the preceding remarks, we will endeavour to deduce from them a satisfactory hypothesis to account for these appearances The sun, it has been said, is an opaque body, surrounded by a lucid atmosphere; you will easily conceive, then, that maculæ are those parts of his surface which happen to be free from luminous decompositions,

compositions, or in other words, which are but slightly, or not at all, covered by the shining matter, and are for that reason exposed to our view. In most cases the real body of the sun is supposed to be visible through its transparent atmosphere, where the lucid substance is not very intense, or where it is removed by some temporary cause. As some of the spots appear below, and others above the surface of the shining fluid, it is reasonable to conclude that the former are the lower parts of the sun's surface, and the latter his mountains, which project beyond the lucid part of his atmosphere. The former are found to vary in their situation, as they may be hidden or rendered visible by any cause which will accumulate or remove the shining matter; the latter are fixed, with respect to the sun's surface, and are those by observations on which the sun's rotation on his axis has been determined. From what has been here said, it is hoped you are tolerably well acquainted with the nature of maculæ: we will now proceed to the consideration of faculæ.

Faculæ, on this hypothesis, are those parts of the solar atmosphere which are brighter, and in general more elevated than the rest. These Dr. *Herschel* supposes to be "more copious mixtures of such fluids "as decompose each other;" or they may be called, larger collections of the luminous fluids, which form the solar atmosphere, according to the quantity, brightness, and depth of which, the faculæ differ in magnitude and intensity. They are more frequently observed near the borders, than towards the middle of the sun's disc, because, as they are supposed to extend beyond the usual level of his atmosphere, those which are near the middle of the disc become edgewise to our view, and are therefore not so easily discernible as those which approach nearer the circumference thereof.

If the hypothesis concerning the nature of the sun, which is recited in this lesson, be admitted, it will readily be acknowledged that that luminary differs but little in his nature from the planets; and perhaps we may be allowed to call the sun, in a popular way, the *central planet*, or the *grand planet*, to which all the others are intimately united, and from which, as from a copious fountain, flows all that is necessary to support, connect, and harmonize the various planets in the system: hence we may advert to the beautiful and instructive observation of the poet, and say—

> The planets of each system represent
> Kind neighbours: mutual amity prevails;
> Sweet interchange of rays, receiv'd, return'd:
> Enlight'ning and enlighten'd! All at once
> Attracting and attracted! Patriot like,
> None sins against the welfare of the whole:
> But their reciprocal, unselfish aid,
> Affords an emblem of millennial love.
> Nothing in nature, much less *conscious* being,
> Was e'er created solely for *itself*:
> Thus man his sov'reign duty learns in this
> *Material* picture of *benevolence*. YOUNG.

LESSON IV.

ON MERCURY.

First Mercury amidst full tides of light,
Rolls next the Sun, thro' his small circle bright,
All that dwell there must be refin'd and pure,
Bodies like ours, such ardour can't endure;
Our earth would blaze beneath so fierce a ray,
And all it's marble mountains waste away. BAKER.

HOWEVER ignorant we are of the nature of
ualities, and how much soever their mode of ope-
ation is concealed from us, if it be but admitted
hat they act in right lines, and that they are pro-
agated from a point, or body, as from a center,
hen it may be demonstrated in a strictly geometrical
anner, that their energy, or intensity, diminishes
a duplicate proportion of the distance from that
enter. Thus, for instance, suppose a person whom
will call Thomas, stands at ten feet distance from
fire, and another, whom I will call James, stands
wenty-feet from the fire; if they are similarly situ-
ted in all respects but that of distance, it may be
demonstrated, that the fire will impart four times as
much heat to Thomas as to James: that is, Thomas's
heat is to James's, as the square of James's distance
from

from the fire, is to the square of Thomas's distance from it.

Considering the sun as the center from whence proceed those rays, or particles, which meeting with proper substances, produce light and heat at the planets, and calculating by the theorem above mentioned, it has been concluded, that if the earth were placed in the situation of Mercury, its medium of heat would be seven times more intense than the greatest heat of the torrid zone is in its present situation. And hence it has been asserted, that if the materials of which Mercury are composed were exactly of the same nature as those of the earth, they could not long remain without being either melted into a fluid, and dissipated into vapour, or vitrified. Have we not then, in the formation of this planet, another proof of infinite wisdom? For, if the world were formed by chance, or, as atheistical writers express it, by the fortuitous concourse of atoms, whence comes it, that Mercury and the Earth should have the materials of which they are composed, so adjusted and arranged as to make them so well adapted for their respective situations, as we have abundant reason to conclude they are?

It will be necessary to premise, that, though the motions of the planets are tolerably uniform and regular, yet they are not exactly so: nor are their orbits or tracts, in which they describe their periodical motions, strictly circular, but rather elliptical; their bodies are not globes, but spheroids, being flatted

ted at the ends of their axes which are called poles, and more protuberant at their middle parts or equators: their orbits are not all in the same plane, but are variously inclined to each other. However, as it is foreign from my design to treat upon them in so particular a manner, I shall content myself with referring you to places where you may find abundant information in these respects. (See the books recommended towards the end of these Lessons.)

Those planets which move in orbits within that of the earth, are called *inferiour*, perhaps more properly *interiour* planets: those whose orbits enclose the earth's are called *superiour*, or more properly *exteriour* planets.

Mercury is the smallest of the inferiour planets, and the nearest to the sun, about which he is carried with a very rapid motion. Hence it was, that this planet was considered mythologically as the messenger of the gods: he was represented emblematically by the figure of a youth with wings at his head and feet, and his caduceus entwined by winged serpents. The character ☿ in present use for this planet is also derived therefrom. Though small, he has a bright appearance, with a light tinct of blue: he never departs 28° from the sun, and by that mean is usually hid in his splendour.

The mean distance of *Mercury* from the sun, is to that of the earth from the sun, as 387 to 1000: hence his distance is about 37 millions of miles. The sun's diameter will appear at Mercury nearly three times as large as at the earth: and the sun's light and heat received there, is, as before observed, about seven times those at the earth.

The diameter of this planet is nearly one third of the diameter of the earth, or about 3000 miles. Hence the surface of Mercury is nearly $\frac{1}{9}$th, and his magnitude or bulk $\frac{1}{27}$th of that of the earth.

His period of revolution round the sun is 87 days, 23 hours, and $\frac{1}{4}$th, hence you may find that he moves in his orbit about the sun at the amazing rate of more than 95000 miles in an hour. His length of day, or time of rotation on his axis, inclination of axis to his orbit, &c. are yet unknown.

Mercury changes his phases in a manner similar to the moon, according as he is differently stationed with regard to the earth and sun: though we may observe that he never appears quite full, because his bright side is only turned directly towards us, when he is so near the sun as to be lost from our sight in his beams. These different phases of his, make it obvious that he does not shine by any light of his own; for if he did, he would always appear round.

As the orbit of this planet is between the earth's orbit and the sun, if it were in the same plane as the orbit of the earth, Mercury would frequently be seen to move across the face or disc of the sun. But as the planes of their orbits are not coincident, this appearance happens less commonly; it is denominated by astronomers, a *transit of Mercury over the Sun's disc*, the planet then appearing like black spot on the face of the sun. The last transit Mercury happened on the seventh of May, in the esent year (1799): other transits are expected to ppen in the years 1802, 1815, 1822, 1832, 1835, 45, and 1848.

LESSON V.

ON VENUS.

Fair Venus next fulfils her larger round,
With softer beams, and milder glory crown'd;
Friend to mankind, she glitters from afar,
Now the bright evening, now the morning star.

BAKER.

VENUS, the second planet from the Sun, is the next which comes under our consideration: the character by which she is denoted in astronomical performances is ♀, which is the same as that which the chymists make use of to denote copper.

The mean distance of this planet from the Sun is about 69 millions of miles, and her magnitude is nearly the same as the earth's, her diameter being something more than 7900 miles. Astronomers have discovered mountains on her surface; and some dark moveable spots, which have been observed on her disc, give us great reason to suppose she has an atmosphere. Her periodical course round the sun is completed in less than 226 days: the time of a complete rotation on her axis was by *Bianchini* assigned to be 24 days and 6 hours; but *Cassini*, with a much stronger appearance of probability says the rotation is performed in about 23 hours,

and

l this assertion is supported by some late obser-
ions accurately made by ***Shroeter***, from which
has determined the time of one rotation to be 23
rs, 21 minutes.

Venus, when viewed through a telescope, is rarely
n to shine with a full face; but has phases chang-
in like manner with the moon: being now gib-
s, now horned; and her illumined part is con-
tly toward the sun. To the naked eye this
et is easily distinguishable, on account of her
htness and whiteness, which exceeds that of any
r planet; nay her lustre is so considerable that
n she is about 40 degrees removed from the sun,
hardly equalled by that of the moon, which
requently a dull light when compared with the
ur and brightness of the beams of the planet.
his state she has been often mistaken for a comet,
is frequently seen in the day time when the sun
es: a phænomenon which is taken notice of by
e of our philosophical poets.

" No stars besides their radiance can display
" In *Phœbus* presence, the dread Lord of day;
" Ev'n *Cynthia's* self, tho' regent of the night,
" Is quite obscur'd by his emergent light:
" But *Venus* only, as if more divine,
" With *Phœbus* dares in partnership to shine."

his planet is a ***morning star***, when she appears
ward of the sun, for she then rises before him;
ese times she is among poets called *Phosphorus*
or

or *Lucifer:* but when eastward of the sun, she shines in the evening after he sets, and is then calle popularly the *evening star*, but poets then give her the name *Hesperus* or *Vesper*. She retains each of these names in its turn about 290 days.

Venus, as well as Mercury, is sometimes seen to transit the sun's disc, in form of a dark round spot. These *transits of Venus* happen but seldom. One was seen in England in 1639; and two in the present century, viz. the one in 1761, and the othe in 1769; there will not happen another until th year 1874.

None of the wandering stars are more celebrate and admired among the ancients, than the one w are now reflecting upon: they had a prodigiou veneration for her, making her their favourite goddess, paying her adoration and all that deity coul claim; they even thought that her power supplie earth, air and sea, and that clouds and tempe disappeared at her presence. But those who dire their contemplations into a proper channel, wi strip the planet of these imaginary honours, a place them where they are really due: we m consider her in all her varied and attendant beauti as a part, a small part only, of the divine workma ship of Him "Who covers himself with light, "with a garment, and has stretched out the heave "like a curtain:" by thus examining with atte tion the separate parts of his wonderful perfor

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ances, we shall reflect with greater pleasure on the whole, and be induced to exclaim,

> These are thy glorious works, parent of good,
> Almighty, thine this universal frame,
> Thus wonderous fair! THYSELF how wond'rous then!
>
> MILTON.

LESSON VI.

ON THE EARTH.

More distant still our earth comes rolling on,
And forms a wider circle round the sun;
With her the moon, companion ever dear!
Her course attending thro' the shining year. BAKER.

IN the earliest ages of the world the generality of mankind entertained very strange notions concerning the form and dimensions of the earth we inhabit: and even in the present enlightened age it is not unusual to meet with persons whose ideas in this respect, are very far from the truth. Those who have not been in the habit of considering this subject in an astronomical point of view, look upon the earth as a very extensive plane, here and there interspersed with hills and vales; they have also a confused notion of its being fixed firmly upon *something*; but upon what, or in what manner, it is impossible for them to tell.

But I would wish you, my young friends, to reflect upon the subject in a more correct manner; to you I must therefore observe, that the earth is in form nearly globular, and partakes of two constant motions, the one about its axis, and the other through its orbit round the sun, like the other planets. To s perhaps some of you may object, and you may vance several reasons for the objection, the prin-al of which will be like the following:—1. It is ugnant to our senses, which represent the earth be flat and immoveable; and 2. It is contrary to words of scripture.

The first of these reasons may be obviated with e, if the subject be considered with a proper ention: thus, the roundness of the earth is con-med by recollecting that it has been frequently led round: that it is round is also proved by con-ering that it's shadow, as projected upon the moon a lunar eclipse, always appears nearly circular, hich would not happen if the earth were not nearly herical;—but the most manifest proof is derived m the considerations directly following. If we nd upon the sea shore and notice a ship sailing m us, we shall first lose sight of the hull or body the vessel, then of the lower parts of the masts d rigging, and as she goes farther off, the upper rts of the masts disappear: also, when a ship mes towards port, the steeples and highest build-gs are first seen by the sailors; as the vessel comes arer they perceive the houses and lower buildings; d presently after the surface of the ground appears. hus it is obvious that the earth is nearly spherical: d the diversifications of its surface with mountains d vallies have no sensible effect in destroying it's hericity; for the greatest hills when compared therewith, bear no greater proportion to the whol than does the little protuberances on the coat orange to the bulk thereof.

The argument alleged against the earth's motio that "no such motion is evident to our senses, is too weak and frivolous to deserve a particul answer; for it is well known that we meet with de ceptions in the sense of vision, in a variety of in stances where the objects viewed are quite famili to us, and when the fallacy is discovered, we hav been surprized that we should be so easily deceived.

As to the second reason before advanced, tho who oppose the astronomical ideas concerning th shape and motion of the earth, because they thin them contrary to revelation, would do well to con sider for what purpose the Holy Scriptures we written. Were they written as a measure of fai or as a rule to regulate our philosophical opinions *Gassendus* does not give a direct answer to th question, but he has made some very pertinent ob servations on the subject, with which I shall he present you. "There are," says he, "two sacre "volumes, the one written, called the *Bible*; th "other *Nature*, or the *World*; GOD having ma "nifested himself by two lights, the one of reve "lation, and the other of demonstration; accor "ingly the interpreters of the former are divines "of the latter mathematicians. As to matters o "natural knowledge, the mathematicians are t "be consulted; and as to the objects of faith, th prophets; the former being no less interpreters, or apostles, from God to men than the latter. And as the mathematician would be judged to wander out of his province, if he should pretend to controvert, or set aside any article of faith from principles of geometry; so it must be granted, the divines are no less out of their limits, when they venture to pronounce on a point of natural knowledge, beyond the reach of any not versed in geometry and optics, merely from Holy Scripture, which does not pretend to teach any thing of the matter."

I shall now proceed to describe to you the earth an astronomical point of view; for I am con- nced that the more attentively you consider it in s light, the more willingly you will throw aside e common prejudices, and place the true result of ilosophical reasoning in their stead.

The earth, considered as an element after the nner of Aristotle, is called *Terra*; but amongst ronomers it has obtained the name *Tellus*, and lenoted by the character ⊖: it is the third planet m the sun, its mean distance from him being 95 llions of miles; and its diameter is found to be 70 miles. It is nearly 365¼ days in completing revolution through it's orbit, which is the length our year: and a complete rotation upon it's axis performed in the compass of a natural day or 24 urs. From mathematical principles it has been nonstrated that the length of the day is somewhat different at different parts of the year, but the difference is very inconsiderable; one day when the sun is in the equinoctial being shorter by 40 seconds than when he is in the tropics. There is also another motion of the earth, which occasions the precession of the equinoxes, but it is of too abstruse a nature to be explained to you in a satisfactory manner, until you have gained a better acquaintance with astronomy.

Here let us pause and contemplate with humility, mingled with satisfaction, the abundant goodness of HIM "Who hangeth the earth upon nothing" to us his creatures. He compels the huge mass of inert matter on which we dwell, to travel with wonderful regularity through the abyss of space, and in it's progress the various parts thereof, are by means of the diurnal rotation, made to feel the effects of the invigorating fountain of light and heat. Were it not for this we should sensibly feel the want of the returning seasons: no more should we see the vallies standing thick with corn; nor should we behold the beautiful verdure of the fertile meadow;—no more would the trees spread forth their foliage, nor would the plants be ornamented with flowers. Or as it is expressed in the language of inspiration—"No longer would the fig-tree blossom, nor fruit be in the vine: The labour of the olive would fail, and the fields could yield no meat: the flocks must be cut off from

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“ the fold, and there would be no herd in the “ stalls.”

Consider this, ye perverse mortals! who argue gainst conviction: consider and tell us, if the above gloomy picture would not be realized, were the hance which you blindly extol, to preside over us. But thanks to the beneficence of the all-wise PRO-ECTOR of erring men, the evils which would be rought upon us under the dominion of chance, are verted:—directed by an ALMIGHTY command, the arth is carried gradually along, and it's motions are egulated in such a manner as are most conducive o the general design: the varied seasons of the year nd the vicissitudes of day and night follow each ther in pleasing gradations; the whole move on with astonishing harmony, and through every part f their progress, the omnipotent conductor is administring to our wants, and bestowing upon us ad-itional blessings. “ Oh! that men would praise “ the Lord for his goodness, and for his wonderful “ works to the children of men*!”

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* It has been customary when speaking of the benefits we njoy, to mention the convenient situation of the earth in the ystem with respect to light and heat; and in particular with re-rd to heat, it has been said, that were we nearer the sun the rth would be burnt, and were it farther off we should be frozen. his method of reasoning might be applied with propriety when was thought that the sun was a globe of fire; but as modern iscoveries have led philosophers to dispute the truth of such an pinion, it was thought better to omit the argument here hinted at.

The earth is attended with a satellite, which adds greatly to our comforts and greatly to our pleasures: I dare say you will wish to be acquainted with it's nature and size, when I tell you that this satellite i no other than the *Moon*, which with a

> ——pleasing light
> Shadowy sets off the face of things. MILTON.

But as this heavenly body is of such importanc as to deserve a separate description, I shall gratif your curiosity in a future Lesson.

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at. However I have in some parts of these Lessons spoken of th degrees of light and heat, in a manner conformable to the mo generally received opinion: I have also in those places where have spoken of the heat produced by the action of the sun's ray generally called it the *solar heat*; as it would not be right to alt the mode of expression most commonly used, until the premis upon which such alteration is grounded, are entirely acceded to.

LESSON VII.

ON MARS.

In larger circuit rolls the orb of Mars
Guiltless of stern debate, and wasteful wars,
As some have erring taught: he journies on,
Impell'd and nourish'd by the attractive sun;
Like us, his seasons and his day he owes
To the vast bounty which from Phœbus flows.

BROWN.

THE next planet which falls under our consider-ion, is called by the same name as *Mars*, the eathen God of war; and very probably, because e appears with a ruddy fiery countenance: among stronomers he is characterized by this mark ♂, hich seems to be a rude sketch of a man holding spear protended. Mars is the first of the four su-erior planets, his orbit being immediately above at of the earth: his mean distance from the sun about 152 of those parts, of which the mean dis-nce of the earth from that luminary is 100: hence is real distance is about 144 millions of miles: he erforms his revolution round his orbit in about 87 of our days, or 667 ¾ of his own days which is e length of his year. The light and heat at this planet (calculating after the manner described i the fourth Lesson) are in proportion to the ligh and heat at the earth, nearly as 43 to 100. Hi diameter or axis is nearly 4200 miles, from henc it may be shewn that his bulk is $\frac{7}{24}$ of the earth's Dr. Hook, in the year 1665, observed several spo in Mars: observations on these spots and their mo tion by the noted astronomers *Cassini* and *Herschel* have at length determined the rotation of this plan on his axis to be performed in 24 hours $\frac{2}{3}$ ver nearly, which is the length of his day.

Mars when viewed through a telescope is ob served to increase and decrease like the moon, wit this exception, that he is never cornicular, or horned from this we may infer that he shines not by hi own light, and that his orbit includes that of th earth.

This planet when viewed by the unassisted ey appears smaller than Venus, and redder; having ruddy troubled colour: whether this arises from th planet being of such a nature as to reflect the re rays of light best, or from a thick atmosphere at tending it, is rather uncertain. But be this as i will, it appears pretty manifest that his sanguin complexion has obtained him a post of eminenc among the pagan deities.

Virgil, and some other of the ancient poets, giv us lively descriptions of him: they represent him riding in a high chariot drawn by two horses, *Fea* and *Terrour*, and that the God may sit at his eas

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his sister *Bellona* is employed in holding the reins and driving. However though earthly poets have honoured him with these attendants, it does not appear likely that he has any in the heavens: for no satellites of his have yet been discovered; though he is the only one of the superior planets that travels through his annual round without attendance.

LESSON VIII.

ON JUPITER.

Next Jove, prodigious planet of the skies!
His orb presents of huge amazing size,
In bulk none equals his enormous mass;
The whole joint system his contents surpass. BROWN.

THUS sang the poet:—his assertion was strictly true, when the general opinion was that there were only six primary planets; but as there has a seventh lately been discovered, and that a large one, there now remains some doubt: however as the diameters of each of the planets are given in these Lessons, my young readers may find if Mr. B—'s assertion will now hold good, when they have leisure to perform the necessary operations.

This planet, has the same name as the grand heathen deity, viz. *Jupiter*, the character by which he is denoted is ♃, to represent the thunderbolts, as some people suppose; this mark is the same as that by which the chemists denote tin.

Jupiter is situated between Mars and Saturn, and is the fifth primary planet reckoning from the sun: his mean distance from the sun is 52 of such parts, of which the earth's distance is 10; hence his real distance is about 490 millions of miles. His annual revolution about the sun is performed in about 4332 days and $\frac{1}{3}$, being nearly 12 of our years; moving in his orbit at the rate of more than 25 thousand miles per hour. The light and heat received from the sun at *Jupiter*, are in proportion to those received at the earth, as 37 to 1000: hence, it is a very providential circumstance that he is attended by satellites; otherwise his inhabitants (I shall give reasons for supposing he has inhabitants, in another place) would be in a very dreary situation.

Jupiter's diameter or axis is more than 10 times that of the earth, and therefore his magnitude more than 1000 times the earth's: his diameter in English miles is 89170; he performs his diurnal rotation on his axis in the short interval of 9 hours and 56 minutes, by which mean his equatorial parts are carried round with about 25 times the velocity of the like parts of our earth; being carried at the amazing rate of 26 thousand miles per hour. This quick succession of days will also be viewed by the attentive philosopher as another instance of divine wisdom: for, as the poet observes

> —In ample compass *Jove* conducts his sphere,
> And later finishes his tedious year;
> Yet swiftly on his axle turn'd regains,
> The frequent aid of day to warm his plains.
>
> BROWN.

But how will the hearts of all religious youths glow with admiration, when they are informed that the axis of Jupiter is so nearly perpendicular to his orbit, that he has no sensible change of seasons! can this be the work of chance? how wisely ordered! for if the axis of this planet were inclined any considerable number of degrees, so many degrees round each pole would be almost 6 years together in darkness. And as each degree of a great circle on this planet, contains more than 700 miles; it is natural to conceive, that vast tracts of land would be rendered uninhabitable, by any considerable inclination of his axis.

Jupiter when viewed through a telescope is found to be surrounded by faint substances called zones or belts. These belts are generally parallel to its equator, which is very nearly parallel to the ecliptic; they are subject to great variations, both in respect to their number and figure: sometimes eight have been seen at once, and sometimes only one; sometimes they continue for three months without any variation, and sometimes a new belt has been formed in less than two hours. From their being subject to such changes, it is very probable that they do not adhere to the body of Jupiter, but exist in his atmosphere. Dr. Smith in his optics has given a curious account of these belts; and the greater part of the writers on astronomy have given descriptions of them.

This planet, when viewed by the unassisted eye, is remarkable for its pure white brightness: indeed it is the brightest of all the planets, except sometimes Venus. This may appear singular when we remember his great distance from the sun; but when we also consider his enormous bulk, the wonder will cease.

In the year 1610, *Galileo* discovered that Jupiter had four satellites, which he called *Medicean Stars*, n honour of the family of the *Medici*, his patrons. This was a discovery very important in its consequences, as it afforded a method of determining the ongitude of places on the earth (by means of the clipses of these satellites) with greater facility and ccuracy than by any other method yet known. hese eclipses also enabled *M. Roemer* to discover nd ascertain the progressive motion of light; and ence Dr. *Bradley* was enabled to explain an apparent motion in the fixed stars, which could not therwise have been accounted for.

LESSON IX.

ON SATURN.

> Still farther off, scarce warm'd by Phœbus' ray,
> Thro' his wide orbit, Saturn wheels away.
> How great the change could we be wafted there,
> How slow the seasons! and how long the year!
>
> BAKER.

THE sixth planet has obtained the same name a *Saturn*, the supposed father of the heathen gods: amongst astronomers he is represented by the ch- racter ♄, to imitate an old man supporting himsel upon a staff; the same character among the che- mists denotes lead; and indeed there is some affinity between the colour of that metal, and the light dusky colour of the planet.

Saturn's mean distance from the sun is about 9 times farther than the mean distance of the eart from that luminary; being nearly 900 millions o miles: and of course the light and heat he derive from the sun are about ninety times less than at th earth.

This planet performs his annual revolution i about 10761½ of our days; being not far short o thirty years. His diameter or axis is more tha 79000 miles, and his magnitude is almost 100

tim

times that of the earth. As it is agreeable to the nature of a planet to revolve on its axis, *Cassini* and others supposed that Saturn had a rotation of this kind, the time of which they endeavoured to determine, but without success. This point has, however, been at length ascertained by the observations of Dr. *Herschel*, from which he has found that Saturn revolves about his axis in ten hours, and sixteen minutes.

Saturn has seven satellites or moons, attendant upon him: but the most surprizing thing observed about this planet is a kind of ring which encompasses his body; astronomers have noticed it very attentively, and some of them have determined it to be about twenty-one thousand miles distant from Saturn, and to be nearly thirty thousand miles in breadth. After paying a very minute attention to this ring, Dr. *Herschel* thinks himself authorised to say, that it is divided into two concentric rings, situated in one plane, which is not much inclined to the equator of the planet.

There are several conjectures with regard to the uses of this ring, and amongst them, the one which tends most to evince the wisdom of the Almighty I must coincide with; this I shall give you in the words of a poet, who has evinced an extensive acquaintance with philosophy, united with that rational devotion which is generally the result of an attentive contemplation of the works of nature.

Muse! raise thy voice, mysterious truth to sing,
How o'er the copious orb a lucid ring,
Opake and broad is seen it's arch to spread
Round the big globe at stated periods led;
Perhaps (it's use unknown) with gathered heat
To aid the regions of that gelid seat,
The want of nearer Phœbus to supply,
And warm with reflex beams his summer sky;
Else might the high placed world, exposed to frost,
Lie waste, in one eternal winter lost. BROWN.

Some persons who object to this observe, that the inhabitants of Saturn have *undoubtedly* constitutions suited to the globe they inhabit: but these objectors may be reminded, that the nature of Saturn's inhabitants may be so tempered as continually to require the aid of this ring to keep them sufficiently warm; it may also serve to remind them in what a deplorable state they would be, were it not for the continual superintendence and presence of the adorable Creator.

LESSON X.

ON GEORGIUM SIDUS, OR HERSCHEL.

Last of the splendid planetary throng,
See Georgium Sidus gently glides along;
For ages from the world conceal'd he stray'd,
Till noted Herschel the discovery made;
His worth should be for ever known to fame,
So let the new found planet bear his name.

It was for ages supposed that there were only six planets in the *solar system:* and the ingenious *Kepler*, a very eminent astronomer, was so firmly persuaded there were no more, that he confesses, one of the three things which he anxiously sought to find the reason of, was,—why the planets were six in number?

It is to the indefatigable application of an astronomer, who has long resided in this country, (and whom I have had frequent occasion to mention) Dr. *William* *Herschel*, that we are indebted, amongst other brilliant discoveries, for that of a planet, which is the fourth of the superior ones, and the farthest from the sun of any yet discovered. This new found planet was discovered on the 13th of March 1781, and is known by two titles: the one of *Georgium Sidus*, was bestowed upon it by the discoverer, in honour of our present Sovereign. The other of *Herschel* is given it by the chief astronomers of all nations, as a proper testimony of respect to the assiduity and abilities of the person who discovered it.

Georgium Sidus or *Herschel*, is characterized by the mark ♅, being the initial of the discoverer's name, with a cross bar, intersecting the horizontal bar of the H, to represent a cross, and thereby to denote, that the discovery of this planet was after the birth of Christ. Herschel's mean distance from the sun is about nineteen times that of the earth, viz. about 1800 millions of miles; he performs a revolution through his orbit in $30445\frac{2}{3}$ days very nearly, being almost ninety of our years; the light and heat he derives from the sun, are about the 362nd part of those at the earth, calculating on the hypothesis before explained. This planet appears of a bluish white colour, and its brilliancy is between that of Venus and the Moon. With a telescope that magnifies about 300 times, he appears to have a very well defined visible disc. In a very fine clear night, when the moon is absent, he may be perceived by a good eye without a telescope.

The time of this planet's diurnal rotation is not yet discovered: his axis is found to be 35865 English miles, and his solidity 24155283745628 cubic miles. How amazing must be the power that could hurl this and the other planets with such rapidity through the liquid ether! but let your admiration not yet cease, for "these are only part of " his ways." Our contemplations on the starry canopy are not yet completed;—

> —Night opes the *noblest* scenes, and sheds an awe,
> Which gives those venerable scenes full weight,
> And deep reception in the entender'd heart. YOUNG.

Georgium Sidus has six satellites already discovered, which are probably of very great utility to his inhabitants. For it is very reasonable to conclude, that there is scarcely any part of this large planet, but what is constantly enlightened by one or other of these moons *.

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* That the system which is described in the first eleven Lessons, claims a preference to all others, will, I think, appear obvious from the following considerations.

I. The planet *Venus* moves round the Sun, and not round the Earth. For through a telescope, it sometimes appears with a bright and round face like the full Moon, and sometimes horned ike the new Moon; and when it appears full, it is seen near the body of the Sun, as well as when it appears horned: which could not be, did it move round the Earth alone, or round neither the Sun nor the Earth. For, if it moved round the Earth alone, or round both the Sun and the Earth, it must be seen sometimes in hat part of the Heavens which is opposite to the Sun. If it moved round neither the Sun nor the Earth, it could not appear both horned and full, when it is seen near the body of the Sun: it remains, therefore, that it revolves about the Sun, and not about the Earth. Hence its orbit includes the Sun, and is within he orbit of the Earth.

II. Applying a similar mode of reasoning, we may conclude, that *Mercury* moves round the Sun in a less orbit than that of *Venus*; because it puts on the same phases with Venus, and is never seen so far from the Sun as that planet is.

III. The orbit of *Mars* includes both the Earth and the Sun; and the Earth is not in the center thereof. For this planet is capable of appearing opposite to the Sun, or in any other situation with respect to that luminary; which could not be, unless it moved round the earth: and it always appears full, or nearly so; which it could not do if it ever came between the Sun and the Earth; hence, it moves also round the Sun. And farther, when Mars is in the opposite part of the Heavens to the Sun, it appears about five times larger than when it is near the Sun; which shews that it is much nearer the Earth in one situation than in the other: the Earth, therefore, is not in the center of its motion.

IV. The like being observable of *Jupiter*, *Saturn*, and *Herscbel* (though, on account of their greater distance from the Sun and us, the diversity in their apparent magnitudes in different parts of their orbits, is not so great as in *Mars*), it is reasonable to conclude, that these planets also have both the Earth and the Sun within their orbits, and that the Sun, rather than the Earth, is in the center of the same.

V. Since, then, the Earth is placed within the orbits of *Mars*, *Jupiter*, *Saturn*, and *Herscbel*, these planets cannot appear to us to stand still, or to go backward, as observations shew they sometimes do appear, unless the earth moves: and since, as has been shewn, *Venus* and *Mercury* revolve about the Sun, and not about the Earth; since also, the Earth is placed between the orbits of *Mars* and *Venus*, and the periodical time of the earth, if it does move, is, in point of magnitude, between the periodical times of those two, it seems quite reasonable to suppose that the Earth revolves about the Sun in the same manner as the planets do; it is therefore reckoned in the number of them.

VI. But what very much confirms this conclusion, is, that stonishing harmony, which upon this supposition, runs through he whole *solar system*: for it is known that the motions of all the lanets, both primary and secondary, are in conformity to one nd the same law; which is, that *the squares of the periodical imes of the primary planets, are proportional to the cubes of their ean distances from the Sun*; and that *the ſquares of the periodical imes of the secondaries of any primary, are to each other, as the cubes f their distances from that primary.* By no other hypothesis which as been yet invented, can the motions of the heavenly bodies be ccounted for with such beauty and simplicity, as by this; nor is here any other system which exhibits the fabric of the universe, that regularity and harmony which is worthy the DIVINE RCHITECT.

LESSON

LESSON XI.

ON THE MOON.

He smooth'd the rough-cast Moon's imperfect mold,
And comb'd her beamy locks with sacred gold;
Be thou, said he, Queen of the mournful night,
And as he spoke, she rose o'erclad with light;
With thousand stars attending on her train. COWLEY.

AMID the beauteous scenes which deck the face of nature, there are very few that have a more pleasing effect, than those which are viewed by the light of the moon. Several of the poets have given noble descriptions of the delightful appearance and effect of a moon-light evening: one of which, by the ancient poet *Homer*, I shall here insert.

——So when the Moon, refulgent lamp of night,
O'er heav'n's clear azure spreads her sacred light,
When not a breath disturbs the deep serene,
And not a cloud o'ercasts the solemn scene;
Around her throne the vivid planets roll,
And stars unnumber'd gild the glowing pole.
O'er the dark trees a yellower verdure shed,
And tip with silver ev'ry mountain's head:
Then shine the vales; the rocks in prospect rise;
A flood of glory bursts from all the skies;

The conscious swains, rejoicing in the sight,
Eye the blue vault, and bless the useful light.

POPE'S HOMER.

Mr. Pope observes that these lines exhibit, in the riginal, the finest night-piece in poetry: the reader ay judge that in the translation they do not appear isadvantageously.

This beautiful luminary, whose gentle beams ren- r the summer evenings more agreeable, and the inter nights less unpleasant, is a secondary planet; ing a satellite to the earth we inhabit, about hich she revolves in an elliptical orbit from one w moon to another in twenty-nine days twelve urs forty-four minutes very nearly. Her mean stance from the earth is 240,000 miles, and she oves in her orbit at the rate of about 2290 miles an hour: her diameter is about 2180 miles; and r rotation on her axis is performed in the same e as her revolution through her orbit: hence it pears that her day and night taken together are t as long as our lunar month.

You have without doubt, very frequently taken tice of the various changes the moon undergoes, you very probably are anxious to see them ac- nted for: I shall here endeavour to satisfy your iosity. The Moon is a dark, or opake body, ing principally with the light she receives from sun; hence, only that half turned towards him ny time can be illuminated, the opposite half remaining dark: then as the face of the Moon visible on the earth, is that part of her body turned towards us, we shall, according to the different positions of the Moon, with regard to the Sun and Earth, perceive different degrees of illumination. Hence the Moon appears sometimes increasing, sometimes waning: sometimes horned, then half round; sometimes gibbous, then full and round. At the time of new Moon, the Moon is between the Earth and Sun; and at the time of full Moon, the Earth is between the Moon and Sun.

This may be familiarly illustrated by means of an ivory ball which being held before a candle in various positions, will present a greater or less portion of its illumined hemisphere to the view of the observer. The Earth presents the same phases to a spectator on the moon, as she does to us, only in a contrary order, the one being full when the other changes, &c. and in a greater degree, the earth giving thirteen times as much light as the moon.

The face of the Moon, as you may have often observed, appears to have shades of different colours: when viewed through a telescope these shades are found to be the diversifications of hills and vallies; the same are also shewn by the border of the Moon appearing indented or jagged, especially about the edge of the illumined part when the Moon is either horned or gibbous. Dr. *Hersche* has measured the heights of several of the luna prominences with greater precision than any of the

forme

ner astronomers: he has determined that very
of them exceed half a mile in their perpendicular
ation. He has also observed several volcanoes
the moon, emitting fire, as those on the earth
and indeed there is very little reason to doubt,
, to complete the similarity between her and the
h, she has also seas, rivers, and an atmosphere.

Christianus Huygens, in his excellent conjec-
es concerning the planetary worlds, says "'Tis
ertain that the Moon has no atmosphere sur-
ounding her;" he then proceeds to give his rea-
s for such an assertion; but he has in this instance
en far short of his usual sagacity; for the exist-
e of a lunar atmosphere has been frequently
ved by later writers from the most manifest con-
erations.

f the Moon shone by a light of her own, we
uld feel a sensible warmth from her rays; but
s a light reflected from the Sun with which she
nes, and is so exceedingly weak and languid, that
greatest burning glass will not collect enough
make any sensible degree of heat. This has been
ounted for, and those who have gone through
computation assert, that the light of the full
oon is ninety-thousand times less than day-light.
w wonderfully is infinite goodness and wisdom
played in this instance! For if the Moon's re-
cted rays produced heat, as the air of the night
uld then have a continual warmth, it is obvious

that it would be prejudicial to the health of ma kind. Can we contemplate such divine goodne and not feel thankfulness for it? surely our hym of adoration to the beneficent Creator should exte as far as the gentle rays of the Moon are diffused.

LESSON XII.

ON COMETS.

At his command, affrighting human kind,
Comets drag on their blazing lengths behind;
Nor, as we think, do they at random rove,
But in determin'd times, thro' long ellipses move;
And though sometimes they near approach the Sun,
Sometimes beyond our system's orbit run,
Throughout their race they act their Maker's will,
His power declare, his purposes fulfil.

BAKER.

OTHER kind of wandering bodies is known
e name of *Comets:* these the common people
lazing stars, because they generally have long
blazing or streaming from them. As these
ordinary bodies are but seldom seen, they are
any persons thought portentous, presaging
extraordinary event; some look upon them as
y signs hung out by divine resentment over a
world: some read in their appearance the
f nations and the fall of monarchies; others
ne they foretel desolating plagues, famines, or
for my own part, I must acquit them of
thing of this kind; though I think it not alto-
impossible that they may be sometime the

means of producing very material changes on globe we inhabit.

Among the various opinions which have been tertained concerning the nature of Comets, tha NEWTON has been, till lately, most generally sented to. According to his hypothesis, Co consist of a very compact, durable, and solid stance, capable of bearing most exceedingly degrees of heat and cold without dissolution; are of an opake nature shining by reflection of sun's light, as the planets do. They move in periods in very long elliptical orbits, having the in one of their Foci; in one part of their orbits approach extremely near to the Sun, and in ano part they are immensely distant from him; so times they come much nearer to the Sun than cury's orbit, at other times they are greatly fa from the Sun than *Georgium Sidus*.

Comets differ in their magnitude, there being veral of them less, and some few greater than Moon: but their dimensions are not determ with accuracy; neither are their periods:—fo one person's life is seldom longer than a Co period, and very frequently not so long, there is little chance of his again seeing a Comet, wh returns near the sun after another revolution thr its orbit, and of course their periods are not cisely fixed.

The tail of a Comet, which is generally its conspicuous part, is thought by NEWTON to

prodi

ligious quantity of fume and vapours, flying off
n its body, as it becomes more and more heated
s approach to the Sun. These tails are some-
s exceedingly long, some having been computed
e 80 millions of miles in length: that they are
urs was thought evident from these considera-
s; first, the fixed stars are often seen through
n; secondly, they appear broader on their upper
than near the head of the Comet; thirdly, the
lie always towards those parts which the comets
just left; and fourthly, they seem most splendid
large immediately after they return from the
—all which is agreeable to the nature of smoke
vapour.

he hypothesis of Newton, as above recited,
been objected to by Dr. *Halley* and Dr. *Hamil-*
who think that the tail of a Comet is formed
atter which has not the power of refracting and
cting the rays of light; but that it is a lucid, or
shining substance, and from its similarity to the
ora-borealis, they think it probable that it is
uced by a similar cause, and is properly an
rical phænomenon.

more recently advanced opinion is that of Dr.
schel, who has affirmed, that after a very dili-
examination, he could not perceive the least
arance of any solid nucleus, as they seemed to
ere collections of vapours condensed about the
er of each. He farther supposed that the orbits
omets are not regular and determinate, as they

have been generally imagined to be, because, he s they are liable to be changed considerably by perturbation of the planets. Perhaps, the n appearance of some Comets, which were predic to appear in these last few years, may serve to c firm this suggestion.

After all, it must be acknowledged, that the p losophy of Comets is, at present, very imperf The discoveries which have hitherto been m (owing to the long intervals which frequently p cede the return of Comets, and their irregular tions), are not sufficiently important to afford thing decisive. The prediction of *Seneca* rem yet to be accomplished, wherein he says, "T
" time will come when the nature of Comets,
" their magnitudes, will be demonstrated, and
" routs they take, so different from the planets,
" plained. Posterity will then wonder, that
" preceding ages should be ignorant of matters
" plain and easy to be known."

LESSON XIII.

ON GRAVITY, WEIGHT, &c.

> This problem let philosophers resolve,
> What makes the globes from east to west revolve?
> What is the strong impulsive cause declare,
> That rolls the pond'rous orbs so swift in air?
>
> BLACKMORE.

WHILST you are reflecting upon the planetary
odies, and considering the regularity of their re-
rning periods, these enquiries will very naturally be
ggested to your ideas: as a research of this kind
nnot be unpleasing, this Lesson will be appro-
iated to that purpose. *Sir Isaac Newton* has
t us no room to doubt that the bodies in the *solar*
stem are

> ——— All combin'd
> And rul'd unerring, by that simple power
> Which draws the stone projected to the ground.
>
> THOMSON.

The sagacious *Kepler* had determined from ob-
vations, that the planetary motions agree with
s regular law, viz. The squares of their perio-
al times are as the cubes of their mean distances

from the Sun or focus of their orbits; and this la
has been since demonstrated by *Newton*, from th
principles of attraction and projectile motion. I
we carry back our researches to the creation of th
world, we might reason in a manner similar to th
following:—In the beginning the GRAND MOVE
impressed such a degree of motion upon these bodie
as, if not controuled, would have whirled them o
ward in straight lines, and to endless lengths, till the
would have been lost to imagination in the aby
of space. But the *gravitating* property (whi
acts in reciprocal proportion to the square of i
distance from the attractive center), being combin
with the *projectile* force, determined their cour
to an elliptical form, and obliged these bodies
perform their destined rounds. Were either
these causes to have its action suspended, the ha
mony of these motions would be disconcerted: we
the projectile force suspended, the planets would
drawn by the attractive power till they fell up
the central body: and if the gravitating force we
suspended, they would be rapidly hurled to an i
conceivable distance, and perhaps would be dissipat
into atoms.

How admirable, how extensive, and diversified
the efficacy of the single principle—*Gravity!*
is this which penetrates the minutest pores of
bodies, and diffuses itself to the remotest limits
the Mundane System: it is this which keeps
planetary orbs, already impressed with motion, eq

oised upon their centers: it is this to which we
ay attribute the pressure of the atmosphere: it is
is which causes the ocean to ebb and flow with
ch wonderful regularity, and yet confines it within
roper bounds: these and other complicated effects
rise from one single cause. And what is Gravity?
Ve know there is such a power, and we know how
acts; but that it is a primary quality essential to
l bodies, is not universally admitted: those who
nquire after the cause of Gravity must be inform-
l that the true cause is the DEITY: for Gravity
ay not improperly be stiled the "*Finger* of GOD;
the constant impression of Divine power;"—in
very other sense the cause is likely to continue un-
xplored by mortals.

But if the cause of Gravity have never yet been
iscovered, shall Gravity itself for that reason be
alled an occult quality, and rejected from philoso-
hy? Those who draw such a conclusion should
ake care lest they advance an absurdity, by which
he foundations of all philosophy may be overturned.
or causes usually proceed, in a continued chain,
rom compound to more simple: and when we have
rrived at the most simple cause we can proceed
o farther. No mechanical explication can be given
f the most simple cause: for, if there could, the
ause would not yet be the most simple. If these
most simple causes, then, may be called occult, and
rejected, for the same reason we may reject those
causes which immediately depend upon them, and
hose also which depend upon these last; and so

on until philosophy be entirely divested of all causes whatever.

By the method Analysis it is that we must trace out the established laws of nature; or that order in which instrumental causes are used in producing natural effects. But, as we rise from effects to causes, the more general are those powers which we discover. Effects apparently contradictory are found to proceed from the same principle. The ascent of light bodies, as well as the descent of heavy ones, is the consequence of the universal gravitation of matter. Cohesion, dissolution, and various phænomena in chymistry, are derived from the attractions of minute particles at very small distances. And, wherever we turn our view, the whole course of nature evidently points out to us, that all the various appearances which we behold flow from a few very general and subordinate causes, which more immediately depend upon the ascendant power of the ONE SUPREME CAUSE, the Author and Governor of the Universe! whose existence and influence are manifested by every the most obvious effect; and of whose power, wisdom, and goodness, we acquire higher and more enlarged conceptions in proportion as we obtain a more complete knowledge of his works.

The laws of nature being discovered, as abovementioned, by analysis, particular phænomena are explained synthetically, by shewing their conformity to these laws. Thus, to shew that the Moon is

etained in its orbit by the force of gravity, is to
hew the agreement between that force, and the
orce by which a stone, or any heavy body, tends
o the center of the earth: that the Moon is con-
inually bent from the tangent of its orbit, in the
ame manner as a body near the surface of the earth
s turned from its rectilinear motion into a curve:
hat both these motions are directed to the same
oint, and agree in quantity: that, if the Moon were
o approach to the surface of the Earth, the force,
y which it is retained in its orbit, would make it de-
cend towards the center of the Earth, through the
ame space which a heavy body falling by its gra-
ity, would descend through in the same time: and
hat if a stone or a bullet could be carried to the
istance of the Moon, and there projected with a
ufficient velocity, it would revolve round the Earth
ike a Moon, for the same reason by which it is
ent into a curve, when projected near the surface of
he Earth. By pursuing these methods *Sir Isaac*
Newton demonstrated the universal gravitation of
matter; and it is now pretty generally allowed that
he same principle of gravity, by which we see all
odies tend towards the center of the Earth, is a ge-
al law of nature, extended to all distances, and to
very body in the universe. Thus it is agreed, that
he primary and secondary planets in our system, as
lso the Sun, are mutually attracted by each other.
But since all attractions are mutual, it will follow,
hat if one or more bodies revolve about another,

which is also attracted by them, that other body will not be at rest; but together with them will revolve round the common center of gravity of the whole system. Hence then, and from the proportions of the quantities of matter of the Sun and the planets, it is found that the common center of gravity of the solar system is never far removed from the body of the Sun, and is generally within its surface. Round this point the Sun itself is continually moved in various directions, approaching or receding according to the different positions of the planets.

Since then all bodies, terrestrial and celestial, on which experiments or observations can be made, are found to gravitate towards each other, what has been before said of the universal extension of Gravity, will be the more willingly acceded to; I hope, therefore, I may now quit this part of the subject without giving any additional arguments in support of the opinion.

Before I conclude this Lesson, I cannot avoid adding a few words to explain the difference between *Gravity* and *Weight*, which appear to me the more necessary, because I am aware that the notions commonly entertained are not very correct.

In order to form an exact idea of the weight of a body, it must be recollected, that Gravity impresses, or has a tendency to impress, on every particle of bodies, in an instant, a certain velocity, with which they would fall, if they were not supported;

and that, abstracting the influence of the air, this velocity would be the same for each of the particles of bodies, whatever be their substance. This being observed, we must understand by the weight of a body, the effort necessary to prevent it from falling; and, it is evident, that in order to this, it is necessary to destroy the velocity which gravity has impressed on every particle. This effort must, therefore, be equal to the sum of the velocities of all the particles. Hence it may be naturally concluded, that bodies the most compact, and which, consequently, contain a greater number of particles in the same bulk, will weigh more than others; because the weight being the sum of the velocities impressed on all the particles, that sum must be so much greater, as there are more material particles contained in the mass of the body.

From what is here said, I would observe with *M. de Condorcet*, that we may see "the necessity of carefully distinguishing between the effect of Gravity, and that of Weight: the former is the power of transmitting, or a tendency to transmit into every particle of matter a certain velocity, which is absolutely independent on the number of material particles; and the second is the effort which must be exercised to prevent a given mass from obeying the law of Gravity. *Weight* accordingly *depends on the mass, but Gravity has no dependence at all upon it.*

LESSON XIV.

ON ECLIPSES OF THE SUN AND MOON.

> Give me the ways of wandering stars to know,
> The depths of heav'n above and earth below;
> Teach me the various labours of the moon,
> And whence proceed th' eclipses of the Sun.
>
> VIRG. GEORG. II.

I DOUBT not but several of you, my young friends, will heartily join in Virgil's petition above cited: and though you perhaps may never have either leisure or opportunity enough to acquire a very great astronomical knowledge; yet I can assure you it is no difficult matter to attain such an acquaintance with the science, as to understand the reason of *Eclipses* of the sun and moon.

You will observe then, that an *Eclipse of the Moon*, is a privation of the light of the Moon, occasioned by an interposition of the body of the earth (as she revolves in her orbit) directly between the sun and moon; by which mean, the Sun's rays are so intercepted that they cannot illuminate the Moon: then

——The

Æ

——The silver Moon is all o'er blood,
A settling crimson stains her beauteous face. 122.

It is at the time of full Moon that lunar eclipses happen; because it is only then that the earth is between the Sun and Moon: neither do they happen every full Moon (as they would do if the orbits of the earth and Moon were coincident) because of the obliquity of the Moon's path with respect to the earth's; but only in such full Moons as happen at the intersection of those two paths, called the Moon's nodes; or at least, on those full Moons which happen but a little distance from the nodes.

The chief circumstances in lunar eclipses, as they are given by the learned Dr. *Hutton* in his mathematical and philosophical dictionary, are as follow: —1. All lunar eclipses are universal, or visible in ll parts of the earth which have the Moon above he horizon; and are every where of the same magnitude with the same beginning and end.—2. In all unar eclipses, the eastern side is what first immerges and emerges again; i. e. the left side of the noon as we look toward her from the north; for he proper motion of the Moon being swifter than hat of the earth's shadow, the Moon approaches from the west, overtakes it and passes through it vith the Moon's east side foremost, leaving the hadow behind, or to the westward. — 3. Total clipses, and those of the longest duration, happen the very nodes of the ecliptic; because the section

tion of the earth's shadow then falling on the Moon, is considerably larger than her disc. There may however be total eclipses within a small distance of the nodes; but their duration is the less as they are farther from them; till they become only partial ones, and at last, none at all.—4. The Moon, even in the middle of an eclipse, has usually a faint appearance of light, resembling tarnished copper; which Gassendus, Ricciolus, and Kepler attribute to the light of the sun, refracted by the earth's atmosphere, and so transmitted thither.—Lastly, she grows sensibly paler and dimmer before entering into the real shadow; owing to a penumbra which surrounds that shadow to some distance.

In addition to these circumstances, some astronomers observe, and it is here added, that no eclipse of the moon can last above 5½ hours, from the Moon's first touching the earth's penumbra, to its last leaving it: but an eclipse of the Moon, by the earth's shadow, perhaps never lasts above 3¾ hours; nor when total, above 1¾ hours.

An *eclipse of the Sun* is an occultation or hiding of the Sun's body from our sight, occasioned by an interposition of the Moon between the earth and sun.

> ——Shorn of his beams, the Sun
> In dim eclipse disastrous twilight sheds. MILTON.

It is by several considered and called an eclipse of the earth, since the light of the Sun is hid from the earth by the Moon, whose shadow involves a part of the earth. The manner of a solar eclipse may be conceived by imagining a small part near the vertex of the Moon's conical shadow, travelling over a part of the earth's surface, and making a complete eclipse to all the inhabitants residing within that track; but no where else; for in the large space around, within the limits of the fainter shade called the penumbra, the eclipse will only be partial.

It will not be difficult to understand that solar eclipses can only happen about the time of new Moon, when the Moon is in conjunction with the Sun. In the nodes, when the Moon has no visible latitude, the eclipses are total: out of the nodes, but near them, the eclipses are partial: the limits are about 17 degrees on each side the nodes:—but there is also much depending upon the Moon's latitude, for it must in these cases be always less than the apparent semidiameters of the Sun and Moon added together.

Some circumstances of solar eclipses, as described by the very ingenious author beforementioned in this Lesson, are, 1. That none of them are universal; that is, none of them are seen throughout the whole hemisphere which the Sun is then above; the Moon's disc being much too little, and much too near the earth, to hide the Sun from the whole disc of the earth. Commonly the Moon's dark shadow covers only a spot on the earth's surface, about 180 miles broad, when the Sun's distance is greatest, and the Moon's least. But her partial shadow, or penumbra, may then cover a circular space of 4900 miles in diameter, within which the Sun is more or less eclipsed as the places are nearer to or farther from the center of the penumbra. In this case the axis of the shade passes through the center of the earth, or the new Moon happens exactly in the node, and then it is evident that the section of the shadow is circular; but in every other case the conical shadow is cut obliquely by the surface of the earth, and the section will be an oval, and very nearly a true ellipsis.—2. Nor does the eclipse appear the same in all parts of the earth, where it is seen; but when in one place it is total, in another it is only partial. Farther, when the Moon appears much less than the Sun, as is chiefly the case when she is in *Apoge* and he in *Perige* *; the vertex of the lunar shadow is then too short to reach the earth, and though she be in a central conjunction with the Sun, is yet not large enough to cover his whole disc, but lets his ring appear as a lucid ring or bracelet, and so causes an *annular eclipse*.—3. A solar eclipse does not happen at the same time in all places where it is seen; but appears more early to the western parts, and later to the eastern; as the motion of the Moon, and consequently of her shadow, is from west to east —4. In most solar eclipses the Moon's disc is covered with a faint light, which is attributed to the reflection of the light from the illuminated part of the earth.—Lastly, in total eclipses of the Sun, the Moon's limb is seen surrounded by a pale circle of light; which some astronomers consider as an indication of an atmosphere of the Sun, because it has been observed to move equally with the Sun and not with the Moon.

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* *Apoge* is that place in which the sun or a planet primary or secondary, is at its greatest distance from the earth: *Perige* is when either of these is at its nearest possible distance from us.

In addition to these circumstances we may observe, that though a solar eclipse may last from beginning to end (at one place on the earth) more than two hours; yet the duration of total darkness can never in the greatest eclipse, be more than 4 minutes, and very commonly not more than 2.

We may also observe, with regard to eclipses of both luminaries, that in general, as many eclipses happen of the Sun as of the Moon: but in any particular place there are more eclipses of the Moon than of the Sun. Again, that though in lunar eclipses the eastern side is first eclipsed, and the eclipse ends on the western side; yet in solar eclipses, the western side is first eclipsed, and ends on the eastern.

As to the number of eclipses both solar and lunar, it may be observed that there cannot in any year be less than two, nor more than seven; the most usual number is four, and it is very seldom that there are more than six.

The satellites of some of the superior planets frequently undergo eclipses and occultations; but as these are unobservable by the naked eye, it would not agree with my design to say more about them. Some of the fixed stars, Aldebaran for instance, is frequently hidden behind the Moon; Jupiter also undergoes occultations of this kind; but of these the bare mentioning may suffice.

LESSON XV.

ON THE FIXED STARS, WITH REFLECTIONS ON THE IMMENSITY OF THE UNIVERSE.

———Who turns his eye on nature's midnight face
But must enquire—' What hand behind the scene,
' What arm Almighty, put these wheeling globes
' In motion, and wound up the vast machine?
' Who rounded in his palm these spacious orbs?
' Who bowl'd them flaming thro' the dark profound,
' And set the bosom of old night on fire?'
Nature's controuler, author, guide, and end! YOUNG.

WHEN you, my young friends, consider the unwieldy size of those celestial bodies on which we have already descanted, and reflect upon the astonishing rapidity of some of their motions; surely you must entertain very high ideas of the GREAT POWER which first launched them in the illimitable void, and causes their motions to continue through the flux of so many thousand years; none having yet mistaken their way, or wandered from their destined paths: —on the contrary, their rotations still proceed in such exquisite regularity and harmony as is best adapted to the perfection of the whole. What awful power, and adorable goodness is here displayed! But our reflections on the heavens must be carried infinitely farther than we have yet extended them.

The gems in the brilliant canopy which remain to be contemplated, are the *fixed stars*; which are chiefly distinguished, as was suggested in the second Lesson, from their never changing their relative situation with regard to each other.

The heavens are divided into three regions, called the Northern and Southern hemispheres, and the Zodiac. The Fixed Stars were classed by the ancients under the outlines of certain figures of birds, beasts, fishes and other animals; and these were called *Constellations*. The number of which is, in the northern hemisphere 36, in the southern 32, and in the zodiac 12. Stars not comprehended in any of these ancient constellations, are called *Unformed Stars*; and others, of a cloudy appearance, are called *Nebulæ*. Of this number are the magellanic clouds near the south pole, which resemble two whitish spots in the heavens, and are well known to sailors.

The last star in the tail of *Ursa minor*, or the *Less Bear*, is called the *Polar Star*, and serves for a guide to mariners; because, on account of its nearness to the north pole, its apparent situation, with regard to the earth, varies but very little throughout the period of the earth's annual revolution. Two of the stars in the constellation of *Ursa Major*, or the *Greater Bear*, are called *the*

Pointers,

ointers, because they always point very nearly to
e polar star.

Those of the fixed stars which are nearest to us
em largest, and are therefore said to be of the first
agnitude; those of the second magnitude, being at
greater distance, seem less; and thus they proceed
regular gradations unto the sixth magnitude,
hich includes all the rest of the fixed stars that are
ible without a telescope. With regard to their
mber, a common observer might be led to sup-
se that even to the unassisted eye they are innu-
erable; but this arises from their being observed in
onfused manner: for it may be proved, that when
ey are divided into proper classes, and reckoned
, those in the visible hemisphere seen without a
escope, amount not to many more than a thousand.

Since the introduction of telescopes into astrono-
cal observations, the number of fixed stars has
en very justly considered as immense; for, to the
eater perfection our glasses are carried the more
rs we discover. The astonishingly immense dis-
ce of the fixed stars from one another, and from
earth we inhabit, is one of the most proper con-
erations for elevating our ideas of the works of
OD. Astronomers have computed from indu-
able principles that the distance of Sirius or
dog star (which is the nearest fixed star) from
is considerably more than two millions of mil-
ns of miles! A distance almost inconceivable!
cannon-ball flying from thence at the rate of

400

400 miles in an hour would not reach us in 57000 years!

The stars being at such great distances from th sun, cannot possibly receive from him so strong light as they shine with: hence on mature reflection it will appear that they shine with their ow native lustre, in like manner with the sun; a since each star is confined to a particular porti of space, we must reasonably conclude that ea fixed star is in reality a sun*.

It is not at all probable that the ALMIGHT whose actions all shew infinite wisdom, and wh does nothing in vain, should create so many glorio suns for no other purpose than to add to our pleasure, and give us an additional glimmering of ligh

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* "That stars are suns, will scarcely admit of a doubt. Th immense distance would perfectly exclude them from our vi if the light they sent us were not of the solar kind. Besides t analogy may be traced much farther. The sun turns on its ax so does the star Algol: so do the stars called β Lyræ, δ Ceph η Antinoi, ο Ceti, and many more; most probably all. Fr what other cause can we so probably account for their periodi changes? Again, our sun has spots on its surface; so has the Algol; and so have the stars already named, and probably e star in the heavens. On our sun these spots are changeable; they are on the star ο Ceti; as evidently appears from the ir gularity of its changeable lustre, which is often broken in u by accidental changes, while the general period continues un tered. The same little deviations have been observed in o periodical stars, and ought to be ascribed to the same cause."

HERSCHE

Tho

ose who are so fond of arrogating divine favours themselves have but a mean opinion of infinite dom; since, by a considerably less degree of ating power, our earth would have received much e light from only one additional moon.

nd canst thou think, poor worm, these orbs of light,
size immense, in number infinite,
ere made for thee alone, to twinkle to thy sight?
esumptuous mortal! can thy nerves descry,
ow far from thee they roll, from thee how high?
ith all thy boasted knowledge canst thou see
heir various beauty, order, harmony?
not—then sure they were not made for thee.

BAKER.

nstead then of one sun and one world only in universe, as the unskilful suppose, our con- plations induce us to acknowledge that there t be an inconceivable number of suns and of ems of planets revolving round them, dispersed ugh the infinitely wide expanse of boundless e: insomuch that were our sun with all the ets revolving about it, annihilated, they would no more missed by an eye that could take in whole creation, than a drop of water from the e ocean.

——" Our single system is as nought in estimate
" When balanc'd with the heav'ns: greater the speck
" Which on the sun-beam dances, when compar'd
" With Taurus, or the Alps, or Caucasus;
" Or on the blade the dew-drop to the sea."

There

These reflections must make us feel a consciou
of our own inferiority: who can help exclaimi
with *David* after a similar contemplation—" Lor
what is man, that thou art mindful of him?"

As there is a general analogy running throu
and connecting every part of the creation, into o
grand whole; and as there is undoubtedly an a
solute similarity between the earth we inhabit a
the other planets in our system: can it be unre
sonable to suppose that they and the planets of oth
systems have plants, and trees, herbs, fruits, &
&c. as we have? Or is it repugnant to nature
imagine that they are inhabited by animals and r
tional creatures? Among numberless argume
which might be adduced, a very good one to sh
the great probability of the planets being inhabi
is derived from the following consideration. Th
is no part of matter that we are acquainted wi
which lies waste and useless: seas, lakes and rive
teem with living creatures; mountains and valli
trees and herbs; grasses and the animals which f
upon them; nay, even the blood and humours
the animals themselves, all have their respective
habitants: surely then, the most numerous and b
bodies in the universe, are furnished with be
adapted to their several situations. What an a
gust conception does this give of the works of
CREATOR! Almost more than the human ima
nation is able to conceive. Millions of suns at i
mense distances from each other; attended by t

millions of worlds moving round them, all in pid motion, yet regular and calm: and these, we y safely infer, are inhabited by millions of milns of rational creatures formed for endless felicity!

—Hail! source of being! universal soul
Of heaven and earth! essential presence hail!
To THEE I bend the knee, to THEE my thoughts
Continual climb, who with a master-hand
Hast the great whole into perfection touch'd!

THOMSON.

When an innumerable multitude of bodies of ormous bulk, are all set in motion, and keep velling through their extensive orbits with such uteous regularity and order, by means of the atction of the suns to which they respectively beg; without having their motions either destroyed directed into other courses: how can we exs our conceptions of the greatness, wisdom, goodness of HIM who made and governs the ole?

By the *word* of the LORD were the heavens nade, and all the host of them by the *breath* of is mouth." (David.) What an amazing ince of omnipotence! How inconceivably great hese his marvellous works evince him to be:

Since the great sovereign sends ten thousand worlds,
To tell us he resides above them all,
In glory's unapproachable recess! YOUNG.

how can we forbear venting our adoration in hymn of praise? Previous to my closing this Lesson I mus therefore insert a hymn indited by inspiration, and translated into our language by no less a christian and poet than Mr. *Addison*.

HYMN. PSALM XIX.

THE spacious firmament on high
With all the blue etherial sky;
And spangled heavens, a shining frame,
Their great original proclaim:
Th' unwearied ſun from day to day,
Does his creator's power display:
And publishes to every land,
The work of an almighty hand.

Soon as the evening shades prevail,
The moon takes up the wonderous tale;
And nightly, to the listening earth,
Repeats the story of her birth;
While all the stars, that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And spread the truth from pole to pole.

What though, in solemn silence, all
Move round the dark terrestrial ball?
What though, nor real voice, nor sound,
Amid their radiant orbs are found?
In reason's ear they all rejoice,
And utter ſorth a glorious voice,
For ever singing, as they shine,
The HAND *that made us is divine!*

END OF THE ASTRONOMICAL PART.

LESSON XVI.

ON THE ATMOSPHERE.

> Diffusing gently it's enlivening pow'r,
> The genial air we all around us feel
> Cheering,—tho' unexplored by human sight.

AS we have now finished our survey of the heavenly bodies, our enquiries will naturally descend to the earth we inhabit: and here the first thing which ttracts our attention is, that thin, transparent, and luid body, called *Air*, which surrounds this terra-ucous globe, and covers it to a considerable height. Or, if we include in our definition the whole of the uid mass consisting of air, electric matter, aqueous nd other vapours, which surrounds the earth and artakes of all its motions; we then make use of e word *Atmosphere*, as a term including the hole. Besides the different kinds of air, it is mani-st that the whole mass of the atmosphere contains considerable quantity of water, together with an terogeneous collection of particles exhaled from solid or fluid bodies on the surface of the earth: nce it may not improperly be considered as a chaos of almost every kind of matter confusedly mingled together.

The uses of the atmosphere are so many and great, that it is absolutely necessary, not only to the comfort and convenience of mankind, but even to the existence of all animal and vegetable life. Experiments which have been frequently made with an instrument called an *air pump*, place it beyond a doubt that without the air or atmosphere, no animal could exist, or even be produced; without its aid all vegetation would cease, neither would there be any great degree of either inflammation or combustion; Sound could not be produced without it, nor would there be either rains or dews to moisten the ground: in short, all our reflections on the atmosphere will tend more clearly to convince us that we continually stand in need of the superintendance of our allwise CREATOR.

Besides other innumerable conveniences which we receive from the atmosphere, one great advantage is, that while the sun shines, it makes the face of the heavens appear lucid and bright; but on the contrary, if there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the Sun was placed: if a person should turn his back to the Sun, he would directly perceive it as dark as night, and the least stars would be seen to shine, as in the clearest night. For in that case there would be no substance to reflect the rays of the sun to our eyes; and of course, those

which

vhich did not fall upon the earth would be spread
ut into infinite space, and would never be re-
lected back to us. But since there is an atmosphere
overing the earth, which is strongly illuminated by
he Sun, it, by its power of reflection, turns the
ght towards us, and makes the whole heavens to
hine with such splendour as to render the light
f the stars invisible in the day-time.

By the mean of the atmosphere it happens, that
hough after the Sun has set, we receive no di-
ect light from the Sun, yet we enjoy its reflected
nd refracted light for some time; so that the dark-
ess of the night does not come on suddenly (as it
vould otherwise do) but by degrees. For after the
rth by revolving on its axis has withdrawn us
om seeing the Sun; the atmosphere (whose re-
ecting part reaches about sixty miles high) will still
illuminated by that luminary: so that for a while
e whole heaven will have some of his light im-
rted to it. But as the Earth goes on in its revolu-
on, the Sun gets farther below the horizon; and
much the less is the atmosphere illustrated by
m: until the Sun is about eighteen degrees below
e horizon, when he no longer enlightens our at-
osphere, and then all that part thereof which is
er us becomes dark.

Likewise in the morning, as soon as the Sun
mes within eighteen degrees of the horizon, he
gins again to enlighten the atmosphere, and to dif-
se his light over the sky: so that its brightness does

still increase, till the Sun rises and makes full d
This kind of illumination between day and nig
which is observed in the morning before the Su
rising, and in the evening after his setting, is ca
Crespusculum or *Twilight*.

The terrestrial atmosphere also refracts those r
which fall upon it from the Sun and Stars, a
changes their directions, by propagating the li
in other lines, and thus making the apparent pla
of the celestial bodies different from their true pla
This refraction causes the Sun to be visible bef
he has risen above the horizon, and to protract h
stay with us after he is set in the evening. Th
is an admirable contrivance to shorten the long a
dismal nights in the frigid zones, and thus to a
to the comfort of the inhabitants of those forlorn r
gions. *Varenius* relates in his geography, th
" to those Hollanders who wintered in *No*
" *Zembla*, the Sun was visible, in a clear sky, fi
" teen days before it actually rose above the horiz
" being yet four degrees below it." And *Ho*
speaking of the same circumstance, says, " Th
" night in that place shortened no less than a wh
" month; which must needs be a very great co
" fort, to all such people as live very far tow
" the North and South poles, where length
" night, and want of seeing the Sun, cannot b
" be very tedious and irksome."

Though it is rather foreign from the immed
subject of this lesson, yet I shall here relate a f

propert

properties of refraction, as it will somewhat tend to elucidate what is abovementioned with regard to the twilight. By manifold experiments we find that the rays of a luminous body even of any visible object when they fall upon a medium or diaphanous body of air or water of a different density from that from whence they first proceeded; do not afterwards go directly in the same straight lines, but are broken or bent, and proceed as though they had been propagated from another point. And if the medium on which they fall be denser than the first, they are bent towards a line perpendicular to the surface whereon they fall at the point of incidence; but if it be a rarer medium, in their bending they recede from the perpendicular.

We observe in nature many effects of refraction: for instance—A staff, one part of which is immersed in water, and the other in air, appears broken; and that part which is in water appears higher than it really is. Again—Take a tub, whose sides are straight, and in the middle of the bottom lay a shilling, or any other visible object, fixed so that it cannot move, then go so far from the tub that you can but just see the object, and stand there till another person fills more than half the tub with water, and the shilling will then appear as though it were removed some distance farther from you: this experiment may be varied several ways.

Another remarkable instance of refraction, is the following:—A person standing by the side of the river Thames at Greenwich, when it is high water there, may see cattle grazing on the marshy meadow on the other side of the river called the *Isle of Dogs*; but when it is low water there, he cannot see any thing of them, they being hid from his view by the bank on the other side the river. This curious effect is probably owing to the moist and dense vapours just above the surface of the water, being raised higher or lifted up with the surface of the water at the time of high tide; the rays passing through these vapours are so much refracted as to render those things visible, which are not to be seen at the time of low water.

But to return from this digression, and proceed with our account of the air and atmosphere: the science which treats of the weight, pressure, and elasticity of the air is called *Pneumatics*. And here it may be first observed, that the air is a fluid body which surrounds and gravitates upon all parts of the earth's surface. But it differs from all other fluids in the following particulars: 1. It can be compressed into a *much* less space than what it naturally possesses, which no other fluid can. 2. It cannot be congealed as other fluids can. 3. It is of a different density in every part upward from the earth's surface, decreasing in its weight, bulk for bulk, the higher it rises; and therefore must also decrease in density; and the densities decrease in such a manner, that when the heights increase in arithmetical progression, the densities decrease in geometrical progression. 4. It is of an elastic or springy nature: and the law it observes in this re-

spect

spect is, that the force of the spring is equal to its weight, or the density is always proportional to the force by which it is compressed. We may also observe that heat increases and cold diminishes the elasticity of the air: or heat expands and cold condenses it.

The weight or pressure of the atmosphere upon any base at the surface of the earth, is equal to the weight of a column of quicksilver of the same base and its height between twenty-eight and thirty-one inches: or equal to the weight of a column of water of the same base and height between thirty-two and thirty-five feet. The first part of this is proved by observations on the *Barometer*, an instrument which measures the pressure of the air; for the limit of barometrical variation is between twenty-eight and thirty-one inches. And the latter part is proved by the sucking pump, which will never raise water higher than thirty-five feet, and sometimes not higher than thirty-two. This variation in the weight of the atmosphere depends in great measure on the different degrees of heat in the air near the surface of the earth; but, perhaps it depends in a much greater degree, on the commotions and changes in the atmosphere from wind, vapours, and other causes.

From the foregoing account of the weight of the atmosphere, it will not be difficult to deduce, that, at a medium there is a pressure equal to nearly fifteen pounds avoirdupois upon every square inch, and this entirely arises from its weight and fluidity. By the combination of these two qualities, which bind down all bodies on the earth with such great force, many wonderful effects are produced: 'tis this which prevents the arterial vessels of animals and plants from being too much distended by the impetus of the circulating juices, or by the elastic force of the air so copiously abounding in them: it is this also which hinders the fluids from transpiring in too great a degree through the pores of their containing vessels, which would otherwise destroy the animal by a debility gradually brought on: to this are also owing many natural phænomena by far too numerous to be mentioned in this place.

Another property of air, and which indeed is its chief criterion, is its elasticity or springiness: it is by virtue of this quality that it dilates itself, after the removal of any pressure; or contracts itself into a less space when it has to sustain a greater pressure. A familiar instance of this quality you may often have observed; namely by having a fresh bladder filled with air; for when squeezed in the hand the air makes a sensible resistance, but when the hand is taken away, the parts which were compressed, directly restore themselves to their former state.

I have before observed that the air presses on a square inch with the weight of 15lbs. on a medium; now if we suppose the surface of a full-sized human body to be ten square feet, which is not too much; we shall find, (as it is the nature of the air to press qually in all directions), that a man who probably upposes he bears no weight, sustains a pressure of o less than 21600lbs. When we consider that the reater part of us are surrounded with such an astoishing pressure, and that this pressure may in the ourse of a very few hours be either increased or iminished by more than a thousand pounds weight; re we never led to reflect upon that POWER who eeps us from utter destruction? Let the Atheist onsider what he has to expect, for his blasphemous enial of so wise and mighty a Being.

Another remarkable property of air, which ought o fill our hearts with thankfulness to the adorable CREATOR, is its transparency: let us recollect in hat a dreary and disconsolate situation we should e if the air were visible. What would then be he use of that noble instrument the eye? Or how hould we discern those diversified and variegated rospects of distant towns, green woods, flowery eadows, fields of corn, &c. which now so often ive us pleasure? Alas! how dismal and gloomy ould be the reverse! Surely our hearts must overow with gratitude to the DIVINE AUTHOR of our xistence, for such unbounded goodness to us his reatures!

LESSON XVII.

ON WINDS.

Trade-winds, observing well their stated course,
To human good employ their powerful force;
The loaded ships across the ocean fann'd
By steady gales, spread commerce through the land:
These you observe—but have you no desire
The hidden spring of such effects t'enquire?
Or, when contending winds around you blow,
Do you ne'er wish the cause of them to know?

HITHERTO our reflections have carried us no farther than to consider the air in a motionless state; but as this fluid mass is frequently in motion, and that too, sometimes, in a violent degree, it would be almost unpardonable to pass by such an obvious effect without paying some attention to it.

Air in a current-like motion is known by the name of *Wind*: though the winds in a temperate zone of the earth are very inconstant and changeable, yet this is not the case in every part of the terrestrial globe; for in the torrid zone and some other parts, the winds are generally very uniform and constant in their direction, as will appear from the following facts relative thereto:

1. Over the Atlantic and Pacific oceans, particu-
rly between thirty degrees of North and thirty de-
rees of South latitude, the *Trade-winds*, as they
re called, blow uniformly from east to west, all
e year round, with a small variation in the diffe-
nt seasons.

2. When the sun is on the equator, the *Trade-*
inds in sailing northward, veer more and more
om the east towards the north; so that about their
nit they become nearly north-east: and *vice versa*
sailing southward, they become at last nearly
uth-east. 3. When the sun is near the Tropic
Cancer, the *Trade-winds* north of the equator,
come more nearly east than at other times, and
ose south of the equator more nearly south; and
e versa, when the sun is near the Tropic of Ca-
icorn. 4. The *Trade-winds* are not due east upon
e equator, but about four degrees to the north
it.

To account for these facts relative to the winds
a most curious and important, though mysterious
quiry; having employed the pens of several very
inent philosophers: but amongst all the explana-
ns I have seen, there is none in my opinion more
reeable to nature than one given by Mr. *John*
lton, of Manchester, in his "Meteorological
servations and Essays" lately published: the
thod of reasoning applied to the subject in that
rk, I shall here make use of.

The inequality of heat in the different climat and places, and the earth's rotation on its axi appears to be the principal causes of all winds, re gular and irregular. It may be observed, that whe ever the heat is greatest, there the air will ascen and a supply of colder air will be received fro the neighbouring parts: it will be willingly allow that the heat is at all times greatest in the torrid zo and decreases gradually in proceeding northward, southward; also that the poles may at all times conſidered as the centres of cold. Hence it reaso ably follows, that abstracting from accidental ci cumstances, there will be a constant ascent of over the torrid zone, which air will afterwards f northward and southward, whilst the colder below is determined by a continual impulse towa the equator.

When the effects of the earth's rotation are ta into consideration, our reasoning must be as fo lows: the air over any part of the earth's surfa when apparently at rest or calm, will have t same rotatory velocity as that part; but if a qu tity of air in the northern hemisphere, receive impulse in the direction of the meridian, eit northward or southward, its rotatory velocity w be greater in the former case, and less in the la than that of the air into which it moves; c sequently, if it move northward, it will hav greater velocity eastward than the air, or surface the earth over which it moves, and will theref

bec

become a south-west wind, or a wind between the south and west. And *vice versa*, if it move southward, it becomes a north-east wind. From similar considerations it will appear, that in the southern hemisphere the winds will be north-west and south-east respectively.

The *Trade-winds* may therefore be explained thus: the two general masses of air proceeding from both hemispheres towards the equator, as they advance are constantly deflected more and more towards the east, by reason of the earth's rotation; that from the southern hemisphere originally a south wind, is made to veer more and more towards the east; in like manner, that from the northern hemisphere is made to change its directions from the north towards the east: these two masses meeting near the equator, their velocities south and north destroy each other, and they proceed afterwards with their common velocity from east to west round the torrid zone, excepting the irregularities produced by the continents. The equator is not in reality the place of concourse, but the northern parallel of four degrees; because the centre of heat is thereabouts, the sun being longer on the north side of the equator, than on the south side. Moreover, when the sun is near one of the tropics, the centre of heat upon the earth's surface is then nearer that tropic than usual, and therefore the winds about the tropic are more nearly east at that time, and those about the other tropic more nearly north and south.

If all the terrestrial globe were covered with water, or, if the variations of the earth's surface in heat were regular and constant, so that the heat was the same in every part of the same parallel of latitude, the winds would then be very nearly regular also: but this is not the case; for we find the irregularities of heat, arising from the interspersion of land and sea, are such, that though all the parts of the atmosphere in some measure conspire to produce regular winds about the torrid zone, yet very striking irregularities are often found to take place. A remarkable instance we have in *Monsoons*, which are winds that in the Indian ocean, &c. blow for six months together one way, and the next six months the contrary way: these with sea and land breezes don't seem easily to be accounted for on any other principle than that of rarefaction.

Perhaps some persons may be led to suppose that the winds in the northern temperate zone should be between the north and east towards the poles, and between the south and west nearer the equator, almost as regular as the Trade-winds: but when the change of seasons, the different capacities of land and water for heat, the interference and opposition of the two general currents be considered, it might be concluded almost next to impossible that the winds in the temperate zone should exhibit any thing like regularity: however notwithstanding this, observations sufficiently evince, that the winds therein are, for the most part, in the direction of

e of the general currents; namely, somewhere
ween the south and west, or more commonly be-
een the north and east; and that winds in other
ections happen only as accidental varieties, chiefly
unsettled weather.

We may have frequently taken notice, that several
nds, particularly stormy ones, are attended with a
oudy sky: to this it may be added, that we have
ore winds than usually occur in rather less lati-
des, where the atmosphere is generally more se-
ne: these considered make it exceedingly probable,
at the aqueous vapours which are sustained by
e air, from whence come clouds and rains, may
one great cause of irregular winds. It has been
termined from very accurate experiments, that one
ch of water when evaporated will fill more than
00 inches of space: from hence it appears that
e water which falls in drops of rain, &c. pos-
ssed more than 2000 times the space when it
oated in the atmosphere in vapours; the conden-
tion thereof must therefore occasion vacua of such
nature, as will cause winds of different kinds and
egrees, according to the deficiency which is to be
pplied.

The œconomy of winds, an illustration of which
as been here attempted, is admirably adapted to the
rious purposes of nature, and to the general in-
rcourse of mankind:—if the earth had been fixed,
nd the sun had revolved about it, the air over the
rrid zone, and particularly about the equator,
would

would have been almost always stagnant; an
the other zones the winds would have had little
riation either in direction or strength; in this c
navigation would have been greatly impeded, an
communication between the two hemispheres
sea, rendered impracticable. On the present sys
of things, however, the irregularity of winds i
the happiest consequence by being subservien
navigation; and a general circulation of air c
stantly takes place between the eastern and wes
hemispheres, as well as between the polar a
equatorial regions; by reason of which, t
diffusion and intermixture of the different ae
fluids, so necessary for the life, health, and pros
rity of the animal and vegetable kingdoms is acco
plished:—such is the transcendant wisdom and p
vidential care of the beneficent **FATHER OF AL**

LESSON XVIII.

ON SOUNDS AND ECHOES.

> ——Sweet music breathe,
> Above, about, or underneath,
> Sent by some spirit to mortals' good. MILTON.

ANOTHER peculiar motion of the air remains t to be considered, which is that by means of hich *sounds* are rendered audible or sensible to us, der all their different affections and circumstances. f the philosophy of sounds *Music* is undoubtedly e essential and most refined part; and we find at people in general are exceedingly fond of mu- al sounds, being thereby affected with the most reeable and ravishing sensations. It is my pro- nce in this place to give no more of the science *Music* than what relates to the production of usical sounds, and indeed of *Sounds in general*, which I shall now proceed[*].

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[*] Though it be somewhat foreign to the subject immediately der discussion, yet I cannot pass by an opportunity of suggest- an obvious improvement in the practice of Music; the use which has been frequently urged, though it be not yet generally

Experiments on the air-pump prove to us that without the assistance of air, sounds cannot be produced; they also evince that the nature of sounds depends entirely upon a certain motion of the particles of air. This motion is a pulsive or vibratory one, carrying the particles thereof forward and

rally acceded to. This improvement is no other than the substitution of proper characters to denote the different kinds and velocities of *musical time*, inſtead of those vague, indefinite ones, which are now in use. What is the information we can obtain from casting our eyes upon the characters $\frac{2}{4}$, $\frac{3}{2}$, $\frac{3}{4}$, $\frac{6}{8}$, &c.? Why truly, no more that can be learned from reckoning up the Crotchets, Minims, Quavers, &c. in the first complete bar in the tune. The characters for the several rates of common time; and the terms Adagio, Largo, Allegro, Presto, &c. &c. are also of very little avail in ascertaining with precision the point the Musician wishes to discover. Every composer of musical airs, &c. would be of real service to the practitioner, if he would point out the absolute rate at which his music is to be performed: this would be no difficult task; as he would only have to mention the length of a pendulum which would make one complete vibration in the time that part of a bar called a beat was performing. Thus, for instance, suppose I set a tune in triple time, and wish to have each bar performed in a second and a half, the character I must make use of is $\frac{3}{10}$; for from this it might be concluded, that there were three beats in a bar, and each of these beats must be performed in the time a pendulum 10 inches long made one vibration.

To explain this method clearly, much more room is requisite; but this would not be a proper place for it: however, those who understand what improvement is intended, from this short account, will, I hope, excuse me for exhorting them to use their best endeavours to make it general.

back-

ackward through the very same space: and it re-
ults from, or depends upon, the spring or elasticity
f the air. It is by means of this power that, when
ny one particle is by any cause urged forward, it
ust necessarily propel the particle next before it;
his second particle, in the same manner, moves a
hird, and so on, successively: and by these means
he motion is propagated in the several particles of
ir, through a certain space in a direction forward:
—but, on the other hand, when the force which
as first imprest upon the elastic particles of air
eases to act, those particles return again, by the
ction of the air's elasticity through the same space.
t is evident that if the producing force be con-
nued on these elastic particles, there must neces-
arily be produced in them a mutual vibratory mo-
ion of each particle, so long as the repercussive
rce continues to act: and this motion of the aërial
articles being continued until it reaches the *ear*, the
ifferent parts, nerves, &c. belonging to and con-
guous to the organ of hearing, being exquisitely
dapted to the purpose, convey the sensation to the
rain, and so produce the idea or perception of
und.

The waves in water and the pulses in air which
roduce sound, though brought about by two dif-
rent causes, gravity and elasticity, are yet some-
hat similar: if a stone be dropped into the water,
will cause waves to be propagated in a circular
rection upon the water's surface all round the point
where

where the stone was dropped in; in like manner, the motion of a sounding body is propagated around it in regular gradations: but the aqueous waves differ from the aërial pulses in this, that the former are of a circular form, being generated on a plane *surface*; but the latter are of a spherical form, because they are produced in the *body* of an elastic fluid.

The kind of motion which produces sound, mu be understood to be that which is brought about by means of the elastic parts of which sonorous bodie consist; for without such an elastic disposition of parts they could not by any means be rendered sonorous, or capable of emitting sounds; because the stroke being made externally, affects the particles of such a body but with one single act; th particles of the body could therefore, in such a case, be moved only through a certain small space, an would there be made to stop by the resistance o the parts beyond: thus without an elastic force th particles would remain at rest, after the percutie body was removed; and therefore, from a singl stroke the parts of unelastic bodies could emit b a kind of blunt, short sound: in such cases it i common to say *we hear the stroke*, as when w strike with a hammer on a piece of lead.

But when we consider the stroke impressed o bodies whose parts are in any considerable degr elastic, they not only yield to the stroke and g forward through a small space, but, after the stri ing body is removed, those elastic parts, by th

renite

itent force, return again with a velocity equal to
t by which they were displaced: and thus a vi-
tory motion being produced, will continue a
sible time, and produce successive impulses on
contiguous air; hence, the air being thus agi-
d by the elastic particles of the body, transmits
pulses successively to the ear, and there produces
sensation of sound of some duration. Thus
ongst sonorous bodies, we notice a wire when
tched and properly struck; also a bell and a
ss, which are some of the fittest instruments for
sical modulations. Much more might be said on
causes of sounds in general, but for a general
a, what has been already mentioned may suffice.

To determine the nature and effect of different
lies in conducting sound, Mr. *George Saunders*
de a variety of experiments: some of his con-
sions and remarks, are as follow:

Earth may be supposed to have a two-fold pro-
ty with respect to sound. Being very porous,
bsorbs sound, which is counteracted by its pro-
ty of conducting it, and occasions it to pass on
plane, in an equal proportion to its progress in
unencumbered by any body. If a sound be
ficiently intense to impress the earth in its tre-
lous quality, it will be carried to a considerable
tance, as when the earth is struck with any thing
d, as by horses feet, or the motion of a carriage.
ster is proportionally better than loose earth for
nducting sound, as it is more compact.

Clothes of every kind, but particularly wooll
ones, are very prejudicial to sound: their absor
tion of sound, may be compared to their absorpti
of water, which they greedily imbibe.

A number of people seated before others, (as
the gallery of a chapel or theatre) considerably pr
vent the voice reaching those behind; and hence
is that we hear so much better in the front of th
galleries, than behind others. Our seats, rising
little above each other, occasion this defect, whi
would be remedied, could we have the seats to r
their whole height above each other, as in the a
cient theatres.

Water has been little noticed with respect to
conducting of sound; but it has been lately fou
to conduct sound more than any other body wh
ever. A conversation delivered in no very lo
tone, has been distinctly heard, on water, at th
distance of a mile; and a whisper has been heard
the distance of more than two hundred yards.

Stone is sonorous, but gives a harsh disagreeab
tone, unfavourable to music. Brick, in respect
sound, has nearly the same properties as stone.

Wood is sonorous, conductive and vibrative;
all materials it produces a tone the most agreeab
and melodious; and it is, therefore, the fittest f
musical instruments, and for lining of rooms a
theatres.

Paint has been generally thought unfavourable
sound, from its being so to musical instrume

hose effects it entirely destroys. Musical instru-
ents mostly depend on the vibrative or tremulous
operty of the material, which a body of colour
rdened in oil must very much alter: but we should
stinguish that this regards the *formation* of sound,
hich may not altogether be the case in the *pro-*
ress of it.

A remarkable circumstance in the nature of sounds,
hich well deserves the attention of my young readers,
, that every substance whatever, whose parts are so
nnected as to be capable of an uniform vibration,
ay have that vibration produced in it by the sound-
g of a certain musical note or tone, with which it is
unison. Thus *Kircher* speaks of a large stone that
ould tremble at the sound of one particular organ-
pe. Mr. *Boyle* states the fact of seats trembling
the sound of organs; he tells us also, that he has
lt his hat to shake under his hand at certain notes,
th of organs and other instruments; and, he was
ld by an experienced builder, that any well built
ult will answer some determinate note. Even
quids, when so suspended as to be capable of vi-
ation, (for example, water in a glass) are observed,
t only to vibrate when a particular note is struck
sounded, but actually sound themselves, in con-
rd. That water suspended in a glass becomes in
ality a sonorous body, is proved by the mode of
ning a set of musical glasses, which become the
aver in tone, the more water is poured into them;
r, were it only the empty part of the glass that

sounded,

sounded, the sound would become more acute, more water is poured in. But, as the contrary the fact, it is thence evident that the water glass together form one compound sonorous stance, of which the greater the quantity or volu the deeper is its musical tone.

From what has been already stated, it will app manifest, that when the producing cause of a sound is at a distance, there must be an interval time elapse before the sound itself can arrive at t ear; and indeed this may often have been manife to us by our own observations. Thus for instan when a gun has been fired at a distance, we m have taken notice that after we have seen the fla some time has elapsed previous to our hearing t report: or again, when a woodman has been fell trees at a distance, we may have observed that interval of time passes away after we have seen t action performed before we hear the stroke. T experiments which have been made to determine velocity of sound, have neither been so numer nor so accurate as could be wished; and on this count it is, that opinions differ concerning the ture of its progressive motion: because the intens of sound diminishes as the distance increases, so persons suppose that the velocity does also; th therefore imagine that the velocity is inversely the distance, and, consequently, the time will be d rectly as the distance: but an opinion which me with more advocates is, that sound moves uniform the rate of 1142 feet in 1 second of time, or ut an English mile in $4\frac{2}{3}$ seconds; and this rate motion being allowed, it will not be any way icult to determine the time for the passage of nd, the distance being given, and *vice versa*, in ariety of cases.

A curious phænomenon with regard to sounds, n *echo*, which is caused by the vibrating air be- hindered in its passage. For, as the air undulates ward like a wave, it often meets with various jects, and by striking against them is reflected k to us, and causes new vibrations, which (if object lie in a proper situation) return to us and eat the same sound, tone, or word, as was first en; and this, it sometimes happens, not only ce but several times.

From this short account of the nature of echoes, will not be difficult to conceive that they also y be applied to the measuring of inaccessible dis- ces: thus, Dr. Derham, standing upon the bank the Thames opposite to Woolwich, observed t the echo of a single sound was reflected back m the houses on the opposite bank in 3 seconds; nsequently the sum of the direct and reflex rays st have been 1142 multiplied into 3, or 3426 t, and the half of it, viz. 1713 feet, the breadth the river in that place.

But to treat upon the nature of sounds in such a nner as the importance of the subject demands ould fill a volume, I must therefore now desist:

from what little has been here mentioned, the contemplative young reader will with pleasure draw this inference: that even in the nature and production of sounds the goodness of the CREATOR to his creatures is conspicuously shewn: for, if bodies had no degree of elasticity, or if the air were not so fluid as to be very easily put in motion, there would be an end of all the melody and harmony which now so much delight us. What praise does that benevolent BEING require from us, who not only administers to us what is necessary for our welfare, but has contrived all around us in so admirable a manner as to be subservient to our pleasures?

LESSON XIX.

ON EVAPORATION, RAIN, HAIL, SNOW, MISTS, AND DEW.

——Th' effusive south
Warms the wide air, and o'er the void of heav'n
Breathes the big clouds with vernal show'rs distent.
At first a dusky wreath they seem to rise,
Scarce staining æther; but by swift degrees
In heaps on heaps, the doubling vapour sails
Along the clouded sky. THOMSON.

Rain.

OUR next business is to reflect upon the means y which the most usual meteors as *Rain*, *Hail*, *Snow*, and the all-enlivening *Dew*, are produced nd in order to this, the first thing we are to consider is the process of *Evaporation*. To have a recise idea of *evaporation*, some persons distinguish it from *exhalation*, and say that the former is the act of dissipating the humidity of a body in umes or vapour, while the latter they say is properly a dispersion of dry particles issuing from a body. Others say there is no need of any such distinction, *exhalation* (properly signifying a *breathing forth*) being applicable to all bodies capable of being respired, whether moist or dry. The term commonly used by chymists for the raising of the minute particles of bodies in a dry form, is *sublimation*, *Evaporation* is by them generally applied to bodies in a state of humidity, and *precipitation* is the falling down of any body, dry or humid, which has been held in solution in any other body.

There are, indeed, few subjects of philosophical investigation that have occasioned a greater variety of opinions than the theory of Evaporation: as such a diversity of opinions yet exist, it is almost next to impossible to advance one, but what may be contradicted, and in some respects refuted: however, be this as it will, among the various theories I shall make use of the following:

Dr. *Hamilton*, Professor of Philosophy in the University of Dublin, supposes that Evaporation is nothing more than a gradual solution of water in air, produced and promoted by attraction, heat, and motion, just as other solutions are effected. To account for the ascent of aqueous vapours into the atmosphere, this ingenious author observes, that the lowest part of the air being pressed by the weight of the upper against the surface of the water, and continually rubbing upon it by its motion, attracts and dissolves those particles which it is in contact with, and separates them from the rest of the water. And since the cause of solution in this case is the stronger attraction of the particles of water towards the air, than towards each other, those that are already dissolved and taken up, will be still farther ed by the attraction of the dry air that lies over m, and thus will diffuse themselves, rising grally higher and higher, and so leave the lowest air so much saturated but that it will still be able to solve and take up fresh particles of water; which ocess is greatly promoted by the motion of the nd. When the vapours are thus raised and rried by the winds into the higher and colder parts the atmosphere, some of them will coalesce into all particles, which slightly attracting each other, d being intermixed with air, will form *clouds*; d these clouds will float at different heights (vary-g, from less than half a mile, to somewhat more an two miles) according to the quantity of va-ur borne up, and the degree of heat in the upper rt of the atmosphere: and thus, clouds are gene-lly higher in summer than in winter.

When the clouds are much increased by a conti-al addition of vapours, and their particles are iven close together, by winds, cold, and other uses, then will they run into drops heavy enough fall down in *Rain*:—

> —The clouds consign their treasures to the fields,
> And, softly shaking on the dimpled pool
> Prelusive drops, let all the moisture flow
> In large effusion o'er the freshen'd world.
>
> THOMSON.

In the winter, when the air is disposed for freez-g, it is not unlikely that the atoms of vapour hich are near the earth are congealed, whereby they become more opacous, and constitute those obscure fogs which attend a hoar frost; at this time the clouds are probably frozen before their particles are gathered into drops, small pieces of them being condensed and made heavier by the cold, fall down in *Snow*:—

Then from aërial treasures downwards pours
Sheets of unsolly'd snow in lucid showers;
Flake after flake, thro' air, thick wav'ring flies,
'Till one vast shining waste all nature lies.
Then the proud hills a virgin whiteness shed,
A dazzling brightness glitters from the mead:
The hoary trees reflect a silver show,
And groves beneath the lovely burden bow. BROOME.

On a close examination, Snow is found to be composed of icy darts or stars united to each other, as crystals of water commonly are, whether they compose ice, snow, or hoar Frost, at angles of 60 or 120 degrees. Its whiteness is owing to the small particles into which it is divided, refracting and reflecting, instead of transmitting, all the rays of light that fall upon it. Ice, when pounded, becomes equally white.

If drops of rain in their falling pass through a region of cold air, they become congealed in their passage, and fall in *Hailstones*: but *Signior Beccaria* supposes that Hail is formed in the higher regions of the air, where the cold is intense, and where the electric matter is very copious.

In the months of October and November, *Fogs*, or *Mists* are more frequent and thicker than at any other period of the year. If we consider the cause of *Fogs*, the reason of this will appear evident. There is, besides the evaporation from the seas, lakes, and rivers, a constant and very large exhalation from the surface of the earth, at all seasons, of water in the form of vapour; and the warmer the ground the greater will be the evaporation. When the air is warmer, or even but a little colder than the earth, the ascent of vapour is not perceptible to the eye; but when the temperature of the air is considerably lower, the vapour as soon as it rises is deprived of part of its heat, the watery particles are brought more into union, and they become visible in the form of steam: it is also essential to the formation of Fog, that there should be little or no wind stirring, in order that the rising exhalations may have full opportunity to condense. The heat of the middle of the days in autumn is still sufficient to warm the earth and cause a large ascent of vapour, which the chilling frosty nights, which are also generally very calm, condense into Fogs.

When vapour is condensed into small drops upon the surface of bodies on the ground, it is called *Dew*; the most apparent difference between Dew and Rain is, that the condensation of vapour in the one case, is made at or near the surface of the body receiving it, and in the other the drops fall a considerable space before they reach the earth; the cause is the same in both cases, namely cold, operating upon vapoury air. At first view it will appear inconsistent that a condensation of vapour should take place in the air resting upon the earth's surface, which is generally supposed to be warmer than that above; but it is an incontestable fact, that after sun-set, and during the night, in serene weather, the air is coldest at the earth's surface, and grows warmer the higher we ascend, till a certain moderate height, commonly between 20 and 100 yards: accordingly we find, that *Dews* and *Hoar-Frost* are more copious in vallies than in elevated situations. When we recollect that winds in great measure prevent the accumulation of Dew, it can scarcely be doubted but it depends upon the above circumstance.

It would be nearly inexcusable to conclude this Lesson, without calling the attention of my young readers, for a moment, to the beneficent and wise laws established by the AUTHOR OF NATURE to provide for the various exigencies of the sublunary creation, and to make the several parts so dependant upon each other, as to form one well regulated whole. In the torrid zone, and it may be added, in the temperate and frigid zones also, in summer the heat produced by the action of the solar rays would be insupportable, were not a large portion of it absorbed, in the process of Evaporation, into the atmosphere, without increasing the temperature thereof: this heat is again given out in winter, when he vapour is condensed, and mitigates the severity of the cold. The dry spring months are favourable o agriculture, and the Evaporation, which then begins to be considerable, absorbs a portion of the heat mparted to the earth by the sun, and thus renders he transition from cold to heat slow and gradual: n autumn the sun's influence fails apace, but the condensation of vapour contributes to keep up the emperature, and prevent too rapid a transition to winter.

Thus have you another page of the *volume of nature* opened to your view; and though descanted upon in a concise manner, I have no doubt but it will be an additional incentive for you to increase in gratitude, reverence, and love for the adorable AUTHOR thereof.

LESSON XX.

ON FROST.

What art thou, Frost! and whence are thy keen stores
Deriv'd, thou secret, all-invading power,
Whom even th' illusive fluid cannot fly? THOMSON.

How admirably wonderful and diversified are the operations of *Frost!* The thronging multitudes of the stars with peculiar brilliancy glitter through the fair expanse, while the Frost pours its subtle and penetrating influence all around; and sharp and intensely severe throughout the long night continues its rigid operations.

Loud rings the frozen earth, and hard reflects
A double noise: while at the evening watch
The village dog deters the nightly thief;
The heifer lows; the diſtant water fall
Swells in the breeze; and with the haſty tread
Of traveller, the hollow sounding plain
Shakes from afar. THOMSON.

When, late and slowly, the morning opens her pale eye, in what a curious and amusing disguise is nature dressed! The icicles, jagged and uneven, hang pendant from the eves, and a whitish film encrusts the windows, where mimic landscapes rise, and fancied figures swell. The fruitful fields are hardened as iron, and the moistened meadows are firmly congealed. The limpid stream is arrested in its career, and its formerly flowing surface chained to the banks. The fluid paths become a solid road; and where the finny shoals were wont to rove, the sportive youths slide, or with rapid motion scate along the crystal pavement. When these and other wonders brought about by *freezing*, are considered, surely it is not unnatural to ask—how are they occasioned? This, perhaps, cannot be answered with the wished-for accuracy: however, though the following observations do not entirely determine the point under consideration, they may yet be somewhat amusing.

The fixing of a fluid body into a firm or solid mass by the action of cold, is called *freezing* or *congelation:* in which sense the terms are applied to water when it freezes into *Ice.* By what mean it is that fluid bodies should thus be rendered solid by cold, the learned have not yet been able to discover: it would seem, however, that it arises from the air then abounding with nitrous and saline particles which insinuate themselves into the pores of water, &c. by which mean they become hard: this is the more probable when it is considered that among *freezing mixtures*, all kinds of salts, whether alkaline or acid, are the principal ingredients.

The process of congelation is always attended with the emission of heat; it is also observed, that water loses of its weight by freezing, being found lighter after thawing again, than before it was frozen. And indeed it evaporates almost as fast when frozen, as when it is fluid: nay, it has been observed, that in Frost the greater the cold, the greater the evaporation; and this, by the bye, furnishes us with a reason why there should generally be more rain fall in February than in any other month.

The manner in which congelation is effected, is now generally thus explained. When water is exposed to an atmosphere colder than itself, it parts with some of its free heat, and is reduced in temperature; but no part of it begins to freeze until the mass is reduced somewhat below the 32d degree of *Fahrenheit's thermometer* *; some of the water then becomes solid, which, by changing its state, sets at liberty a quantity of its combined heat, which restores the fluid in contact with it to the temperature of 32 degrees, or rather above it. The congelation is therefore rather at a stand, till this sensible heat is abstracted by the atmosphere, and the mass reduced somewhat below the 32nd degree. Another portion of water then congeals, and the process is again stopped by the emission of heat. In this

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* For a few remarks relative to this instrument, the Reader is referred to the Appendix.

anner congelation proceeds, and is performed at
tervals which are very observable when the phæ-
menon of freezing is accurately attended to.

Water which has been boiled, freezes more rea-
y than that which has not been boiled: it is also
served, that a slight disturbance of the fluid dis-
ses it to freeze more speedily. Water having its
rface covered with oil of olives, does not freeze so
dily as without it; and *nut-oil* absolutely pre-
rves it under a strong frost, when olive-oil would
t. The surface of water in freezing, appears, as
were, wrinkled: the wrinkles being sometimes in
rallel lines; but more commonly they make angles
about 60 degrees with each other, and some-
es they are like rays proceeding from a centre to
circumference.

Another circumstance relative to the congelation
water I cannot forbear mentioning, as it is very
markable. When water is cooled to within eight
nine degrees of the freezing point, it not only
ses to be farther *condensed*, but is actually *ex-*
nded by farther diminutions of its heat; and this
pansion goes on as the heat is diminished, so long
the water can be kept fluid: and when it is con-
ted into ice, it expands even still more, and the
floats on the surface of the uncongealed part of
fluid. This is the more extraordinary, as it is
exception to one of the most general laws of na-
e with which we are acquainted. It is also
rth while to remark, that though in temperatures

above blood-heat, the expansion of water with heat is very considerable, yet in the neighbourhood of the freezing point, it is exceedingly small. Now it is evident, that when the specific gravity of a liquid is but little changed by any given change of temperature, the motions among the particles of the liquid occasioned by this change must be very sluggish, and the communication of heat, of course very slow, and hence from the preceding account of congelation, its process must also be slow.

Count Rumford, (whose reasonings on this point are very ingenious, and have been farther extended than any other person's), draws from the circumstance an observation which I cannot forbear presenting to my young readers. " Suppose," says he, " that in the general arrangement of things it
" had been necessary to contrive matters so that
" water should not freeze in winter,—or that it
" should not freeze *but with the greatest difficulty*;
" —very slowly ; *and in the smallest quantity pos-*
" *sible*;—How could this have been most readily
" effected ?

" Those who are acquainted with the law of the
" condensation of water, on parting with its heat,
" have already anticipated me in these speculations;
" and it does not appear to me that there is any
" thing which human sagacity can fathom, within
" the wide extended bounds of the visible creation,
" which affords a more striking or more palpable
" proof of the wisdom of the CREATOR, and of the

“ special care he has taken in the general arrange-
“ ment of the universe to preserve animal life, than
“ this wonderful contrivance: for though the ex-
“ tensiveness and immutability of the general laws
“ of Nature impress our minds with awe and re-
“ verence for the Creator of the universe, yet *ex-*
“ *ceptions to those laws*, or particular modifications
“ of them, from which we are able to trace effects
“ evidently *salutary* or advantageous to ourselves
“ and our fellow-creatures, afford still more strik-
“ ing proofs of contrivance, and ought certainly to
“ awaken in us the most lively sentiments of ad-
“ miration, love, and gratitude.”

Though we cannot speak with confidence and ertainty as to the secondary causes by which many f the wonderous effects of congelation are brought bout, we cannot, surely, be at a loss to ascribe hese and every other effect which takes place in the ifferent seasons, to the great FIRST CAUSE. With egard to the attendants of winter, they ought, hough cold and dreary, to warm our hearts with he fire of *Charity*:—ye that sit easy and joyous, in your commodious apartments, solacing yourselves n the diffusive warmth of your fire; O! re-ember, that many of your fellow-creatures, amidst ll the rigour of the inclement skies, are emaciated ith sickness, benumbed with age, and pining with unger. Think! for heaven's sake, think,

—How many drink the cup
Of baleful grief, or eat the bitter bread

Of misery! sore pierced by wintry winds,
How many shrink into the sordid hut
Of cheerless poverty! THOMSON.

While a few faint and dying embers on the squalid hearth, rather mock their wishes than warm their limbs. Methinks every piercing wind that blows, and every addition to the severity of the frost pleads for the poor indigents: may they breathe pity into your breasts, and may you be thereby induced to succour them in their distresses, relieve them from their calamities, clothe their naked bodies, and mitigate the severities of their wants; thus shall you obtain their prayers, and bring peace and comfort to your own souls*!

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* As the following sentences have an affinity to the persuasive above given, I hope an apology for inserting them here is wholly unnecessary.

"When the fatherless call upon thee, when the widow's heart is sunk, and she imploreth thy assistance with tears of sorrow; O pity her affliction, and extend thy hand to those who have none to help them.

"When thou seest the naked wanderer of the street shivering with cold, and destitute of habitation, let bounty open thine heart; let the wings of Charity shelter him from death, that thine own soul may live."

"Whilst the poor man groaneth on the bed of sickness, whilst the unfortunate languish in the horrours of a dungeon, or the hoary head of age lifts up a feeble eye to thee for pity; O how canst thou riot in superfluous enjoyments, regardless of their wants, unfeeling of their woes?"

ECONOMY OF HUMAN LIFE.

LESSON XXI.

ON ELECTRICITY.

> Electricity possesses much of what is admirably adapted to dis-
> ipline the mind. . . . . Let your resolutions then be formed
> o study it as a science, in all its tendencies favourable to the
> eneral interest of knowledge, and to your own particular im-
> rovement, MORGAN.

BEFORE I attempt to explain to you the nature of
hunder-storms, which will be the business of the
ext Lesson, it may be advantageous to appropriate
few pages to the subject of *Electricity*, as it will
end to elucidate what may be said relative to these
hænomena.

Electricity (derived from the Greek name for
mber) is that power or property, which was first
bserved in amber, and which sealing-wax, glass,
nd a variety of other substances, called Electrics,
re known to possess, of attracting light bodies, such
chaff, fine thread, and bits of straw, when ex-
ited by heat or friction; and which is also capable
f being communicated in particular circumstances
other bodies. The term is also, often, more ex-
nsively applied to all other similar powers or pro-
perties,

perties, and their various effects, in whatever bodies they reside, or to whatever bodies they may be communicated.

If a tube of glass, an inch and an half in diameter and about three feet long, be rubbed, by repeatedly drawing the hand, or a piece of leather from one end to the other, it will become electric: so that small flashes of divergent flame, ramified somewhat like trees bare of leaves, will dart into the air, from many parts of the surface of the tube, to the distance of six or eight inches, attended with a crackling noise; and sometimes sparks will fly along the tube to the rubber at more than a foot distant. This luminous matter is called the *Electric Matter* or *Fluid*, and all bodies that we are acquainted with, have more or less of it in them; though it seems to lie dormant till it be put in action by rubbing, and then (in a dark room) it appears like fire.

Some bodies freely admit this fluid, and let it pass through their pores; others do not. The former of these are called, *Non-electrics*, or *Conductors*: of this sort are all metals, living-creatures, water, and moist wood; but metals are found to be the best conductors. The latter, which do not allow the Electric Fluid to pass through their pores, are called *Electrics*, or *Non-conductors*: of this kind are glass, wax, rosin, dry glue, baked wood, and silk. But if either of these be wetted with water, the water that adheres to it will render it a conductor; consequently, when any body is to be used as a non-conductor, it should be well wiped with a dry warm cloth, to clear it of damps, which it may have contracted in a variety of ways. The quantity of Electric Matter which every body has lying dormant in it, is called its natural quantity; and this would always remain motionless and invisible if nothing disturbed it. But when any more is forced into it, as suppose at one end, the whole is instantly put into motion thereby, and begins to be driven out at the other end, if it can find a passage.

The earth is the grand source of the Electric Fluid, and no additional quantity can be forced into any body but from the earth. If the body be a free conductor, and has a communication with the earth by means of any other conducting substance, as metal, or by a table, to the floor and walls of a room, and from thence to the earth, the Electric Fluid will run as fast from the conductor to the earth, as it is by any means driven into the conductor. But, if the communication between the earth and the conducting body be cut off by means of any non-conductor, some of the Electric Matter may be forced into the conductor, by which means it will have more than its natural quantity; and the earth, from which that additional quantity comes, will have so much less: which could never be, if the Electric Fluid were not of an elastic nature, or could not be compressed.

When any body has more than its natural quantity of this fluid, it is said to be electrified positively, or *plus*; and when it has less than its natural quantity,

tity, it is said to be electrified negatively, or *minu* When bodies are electrified either of these way they repel each other; but if some be electrified *plu* and others *minus*, they mutually attract: or if one body be electrified *plus*, and the other no way at all, they also attract each other.

The following experiments will tend to shew th reality of electrical attraction and repulsion. Cu two bits of cork into the shape and size of a common pea. With a needle, draw a thread throug each of the corks, so that they may be made to han at the ends of the threads with a knot below the Let the other ends of the threads be inserted in th notch of a small piece of wood, about a foot lon an inch broad, and the thickness of a commo match. Lay the piece of wood over the mouths two wine glasses, a few inches asunder, so that th end of it, in which the threads are, may project ov the edge of the glass nearest it, and the corks m be in contact with one another. Take anoth wine glass; and, having rubbed it heartily with piece of flannel, or upon the skirt, or sleeve, of woollen coat, hold its mouth to within about inch of the corks, and they will suddenly start a der, and continue so for some time.

Again, lay a pocket watch upon an horizo table, and take a common tobacco pipe, and plac on the face of the watch so that it may rest there in *equilibrio:* then, after rubbing a wine glass, (described in the former experiment) bring it ithin an inch of the smaller end of the tobacco ipe, and by moving the glass gently round in an orizontal circular track, you will cause the pipe to rn round on the watch-glass, as the needle turns n its center in a mariner's compass.

A great many experiments may be performed ith the help of an Electrical Machine; which may e bought, with the necessary apparatus, at the shop f any philosophical-instrument maker in London: it, as it is probable that several persons may wish try Electrical Experiments, who cannot well fford to purchase a complete machine with appa- tus, I shall here give a description of a very simple achine, and one that may be made at but little ex- ence*. It consists of two plates of a circular rm; the under plate may be of wood, glass, or ass, five inches in diameter, and covered on the pper side with an even coat of melted sealing-wax the second quality. The upper plate may be ade of wood, coated entirely with tinfoil, having handle of baked wood, or glass, fixed in the center its upper surface. Or it may be made of tin, ired and soldered round the edges on the upper le, with a small socket in the center for fixing the ndle. The socket and handle may be coated with elted sealing-wax dissolved in spirit of wine. If e under plate be made of wood, glass, or sulphur, it may be coated on the under side with tinfoil, fix on with stiff paste.

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* This simple Electrical Machine is described in No. II. of *the udent*, a periodical work, sold by Mr. *Johnson*, St. Paul's urch yard.

To use this machine: First, with a dry, war piece of flannel, rub briskly that side of the und plate which is covered with sealing-wax, place it o a table with the excited side upward; set the upp plate exactly on the lower, touch the upper pla with the finger, then raise the upper plate by th handle, and it will give a spark of Electric Fire t any conducting substance. By repeating the operation, another spark may be obtained, and so on. I the upper plate be not touched with the finger, o some conducting substance, no spark can be obtained If the sparks be given to the ball of a coated* phial it will become charged, and the electric shock ma be given.

Having said thus much concerning an Electric Machine, I will proceed to describe a few more e periments.——If one body, as suppose a piece o metal be kept for some time in an electrified stat y means of the machine, and an unelectrified light ody, as suppose the down of a feather, be brought ear the metal, the feather will be attracted thereto, nd electrified thereby: on which it will be immeiately repelled from it, and will not return to it gain, till after it has touched some unelectrified ody that is of the conducting kind, and deposited s fluid therein, and then if the distance be but mall, as about two or three inches, it will return the electrified metal as before, and be repelled om it again.

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* Bottles may be easily coated in the following manner:—Ta bismuth *two* parts, lead and tin of each *one* part, melt them t gether and carefully skim off the dross; remove the mixture fr the fire, and before it grows cold add *ten* parts of hot mercury stir the whole together, and the amalgam, when cold, is fit f use. Let the bottle, to be coated, be quite new and clean; p into it a sufficient quantity of the amalgam, incline the bott and gently turn it round, that the composition may adhere t every part, pour out the superfluous amalgam, and the bottle w be beautifully coated.

If a round piece of metal be electrified, and any ointed piece of metal be held near it, the point will aw off the fire from the electrified metal, if that hich has the point be supported by any conducting bstance.

If the middle of a wire, that is pointed at both ds, be fixed to a stick of wax, and either of e points be held near the metal which is kept in electrified state by the machine, that point will aw off the fire from the metal, and the fire will n off from the other point into the air. From is we learn, what is very remarkable, that metal- points throw off, as well as attract Electric Fire. ould this experiment be made in a dark room, the ectric Matter drawn from the metal would appear e a round spark on the point that attracts, and ould be seen going off in the form of a cone from e other point.

If a large globe of metal be electrified positively, it will retain the Electric Fire for some considerabl time. For the surrounding air prevents the accumulated fire from issuing so fast from the globe a it otherwise would. . . . . If two globes of meta be hung by silk lines, or placed on wax, at abou two feet from each other, and one globe be the electrified, and the other be hung, or placed, rathe nearer it; the former will soon lose part of th Electric Matter, which will be drawn off by th latter; but the point of a needle would draw it o much sooner.

Writers on Electricity give accounts of a varie of experiments in this entertaining science, fro which some of the properties of the Electric Matt may be deduced; but as to its real nature philosophers have entertained very different sentimen Some have supposed that it is the same with t ether of Sir Isaac Newton, to which the attracti and repulsion are ascribed; whilst the light, smel and other sensible qualities of the fluid, are refer to the grosser particles of bodies driven from th by the forcible action of this ether; and other a pearances are explained by means of a subtile m dium diffused over the surfaces of all bodies, an resisting the exit and entrance of the ether; whi medium, it is supposed, is the same with the Electr Fluid, and is more rare on the surfaces of co ductors, and more dense and resisting on those o Electrics. But Dr. Priestley (whose abilities a

penetrati

enetration, as a philosopher, are too well known to eed any encomium from me), objects, in some easure, to the hypothesis above recited, and gives as his opinion, founded on experiments, that the lectric Matter either is phlogiston, or contains it; ince he found that both produced similar effects. Ir. Henley also apprehends, that the Electric Fluid a modification of that element, which, in its uiescent state, is called phlogiston; in its first ctive state, Electricity; and when violently agitated, re.

This Electric Fluid, it is supposed, moves with reat ease in those bodies that are called conductors, ut with extreme difficulty and slowness in the pores f Electrics; whence it comes to pass, that all Electics are impermeable to it. It is farther supposed, at Electrics contain always an equal quantity of is fluid, so that there can be no surcharge or inease on one side, without a proportionable deease or loss on the other, and *vice versa*; and as e Electric does not admit the passage of the fluid rough its pores, there will be an accumulation on e side, and a corresponding deficiency on the her. Then when both sides are connected toether by proper conductors, the equilibrium will restored by the rushing of the redundant fluid om the overcharged surface to the exhausted one. hus also, if an Electric be rubbed by a conducting bstance, the Electricity is only conveyed from one the other, the one giving what the other receives;

and,

and, if one be electrified positively, the other wil be electrified negatively, unless the loss be supplied by other bodies connected with it. This theory serves likewise to illustrate the various phænomena and operations in the science of Electricity: thus, bodies differently electrified will naturally attract each other, till they mutually give and receive a equal quantity of the Electric Fluid, and the equilibrium is restored between them. Beccaria supposes that this effect is produced by the Electric Matter making a vacuum in its passage, and the contiguous air afterwards collapsing, and so pushing the bodie together.

It is natural to imagine, that a power of such efficacy as that of Electricity, might be applied wit advantage to medicinal purposes; especially since i has been found invariably to increase the sensible perspiration, to quicken the circulation of the blood, and to promote the glandular secretion: accordingly, many instances occur in the history of this science, in which it has been applied with considerable a vantage and success. In most disorders in which i has been used with perseverance, it has given a least a temporary and partial relief, and in many i has effected a total cure. Electrical shocks, pr perly applied, have frequently cured the ague, tooth-ach, head-ach, rheumatism, pain in the stomach sore-throat, and sometimes the gout; deafness o several years continuance has been removed, and i one case, a person who had been deaf from his birth

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as cured by Electricity: it has cured chilblains, nd removed hard swellings in various parts of the ody; it has been successfully applied in bad spas- odic and paralytic cases, it has cured the St. itus's dance, and it has in one case, if not more, estored sight to the blind.

Since the science of Electricity has been applied the desirable purpose of restoring health to the ck, the emaciated, and infirm, often with consider- ble success, even by gentlemen who are not phy- cians, and consequently cannot be supposed to stinguish always between cases where it may, and here it may not, be advantageously applied; it is uch to be lamented, that medical gentlemen of ill and judgment do not, more generally than they ave hitherto done, give directions for the use of e Electrical Machine, and point out in what cases e may have recourse to it with benefit and safety, d in what cases it would be prejudicial. For I am onvinced, that were such directions laid down and operly disseminated, many benevolent persons in fferent parts of the kingdom would, with alacrity, mbrace the many opportunities which would be en afforded them, of removing the infirmities, and laying the excruciating pains of their indigent eighbours; thus alleviating distress, and restoring omfort and joy to those who may have been long essed down with a weight of lingering disease and ccumulated affliction.

From perusing the imperfect account which I have here given of the science of Electricity, I hope you will be induced to labour after a more familiar acquaintance with it. Be assured that it possesses every property which can make knowledge interesting to the human mind: the power whose laws, whose relations, and whose effects it investigates, has been proved to be one of the most extensive in nature: there is scarcely any science, the light of which may not be increased by it: many are the arts in social life to which it will communicate new powers, and many are the mysterious circumstances in the history of nature and mankind, which by it may probably be developed and explained.

It must be acknowledged, however, that this science is, as yet, in its infantine state; the language by which it is taught is imperfect and obscure; and though various laudable attempts have been made by philosophers of eminence and celebrity, to gain it a respectable place among its sister sciences, it is rarely made an object of eager and complete attention, or of that persevering activity, by which alone it can rise to its proper consequence and maturity.

LESSON XXII.

ON THUNDER AND LIGHTNING.

—By conflicting winds together dash'd,
The Thunder holds his black tremendous throne:
From cloud to cloud the rending Lightnings rage;
'Till, in the furious elemental war
Dissolv'd, the whole precipitated mass
Unbroken floods and solid torrents pours. THOMSON.

AMONG the numerous phænomena which you ave observed, it is scarcely probable that there are ny which should more tend to raise in your mind erious reflections, than that which we are now bout to consider. The more than usual gloomiess of the sky,—the uncommon heat of the air,—e astonishingly rapid descent of the rain or hail, hich generally attend the *Thunder's* tremendous ap, and the *Lightning's* forked flash, do undoubtlly all contribute to raise ideas of wonder and awe. ut when we reflect upon the terrible effects which is meteor produces,—buildings set on fire,—huge ees split into shivers,—steeples rent,—animals and en destroyed,—and metals melted like wax;—hat emotions do we feel? The guilty soul will in a manner shrink into itself with terror: but th truly religious and philosophic mind, whilst fill with admiration of the Power which produc such a meteor as Thunder and Lightning, will b naturally led to enquire by what natural means it i occasioned.

An opinion very prevalent among philosophe until late years, was, that this dreadful and dange-ous meteor is produced by a variety of *acetou* *bituminous*, *spirituous*, *nitrous*, and *sulphureo* particles, exhaled from various bodies, and rais into the air; and there being driven to and fro b the wind and other causes, are at length violentl agitated, and furiously striking against each othe force themselves through the clouds, attended wi an explosion which we call *Thunder*, and a fla or flash which is called *Lightning*: the bitumino and sulphureous particles causing the flash, and th nitrous particles occasioning the explosion.

But it is now universally allowed, that the mete we are now descanting upon is an electrical one the proof of this was reserved for Dr. *Frankli* who is so justly celebrated for his many discoveri particularly in that branch of natural philosop which was the subject of the preceding less This philosopher traced out with much accura several particulars in which Lightning and the ele-tric spark agree; a few of these I shall here me-tion.

Flashes of lightning are generally seen crooked, nd waving in the air: this is also the case with the lectric spark, when it is drawn from an irregular body at some distance. Lightning strikes the highest nd most pointed objects in its way, preferably to others: in like manner, all pointed conductors receive or throw off the electric fluid more readily than such as are terminated by flat surfaces. Lightning takes the readiest and best conductor: so does the electrical fluid. Lightning burns: so does electricity. Lightning sometimes dissolves metals: so does electricity. Lightning has been often known to strike people blind: and pigeons and other small birds have been struck blind by electricity. Lightning sometimes destroys animal life: animals have likewise been killed by electricity.

But what demonstrates in the clearest manner possible the identity of electrical fire with the matter of Lightning, is, that the Doctor, astonishing as it must have appeared, contrived actually to bring Lightning from the heavens by means of an electrical kite, which he raised when a storm of thunder was coming on. The same experiment has been frequently repeated by other philosophers; and it is to be lamented, that it was once attended with fatal consequences: for the *Abbé Richman* was killed by a flash of Lightning he drew down from the clouds in an experiment he was making at Petersburgh.

To know that Lightning and electric matter are the same, is a great step in natural philosophy; but, so long as our acquaintance with the properties of electricity continues so very imperfect, we must necessarily remain ignorant of the causes of many of the appearances which accompany Thunder-storms. However, we will now proceed to give such an explanation of the phænomena, as the present state of knowledge will permit: many observations and experiments tend to prove that some clouds are in a positive, and some in a negative state of electricity; and from other experiments it has been inferred that the quantity of electric matter in a common Thunder-storm, is inconceivably great, considering how many pointed bodies, as steeples and trees, are continually drawing it off, and what a prodigious quantity is repeatedly discharged to or from the earth. This matter is in such abundance, that it is thought impossible for any number of clouds to contain it all, so as either to receive or discharge it. During the progress and increase of a storm, it has been observed, that though the Lightning frequently struck to the earth, the same clouds were ready the next moment to make a still greater discharge: whence it is concluded, that the clouds serve as conductors to convey the electric fluid from those parts of the earth that are overloaded with it, to those that are exhausted of it. The same cause by which a cloud is first raised, from vapours in the atmosphere, draws to it those which are already formed, and still continues to form new ones, till the whole collected mass extends sufficiently far to reach a part of the earth where there is a deficiency of the electric fluid, at which place the electric matter will discharge itself on the earth. A channel of communication being thus formed, a fresh supply of electric matter is raised from the overloaded part, which continues to be conveyed by the medium of the clouds, 'till the equilibrium of the fluid is restored between the two places of the earth. The Lightning throws before it the parts of conducting bodies, and distributes them along the resisting medium through which it must force its passage; the longest flashes seem to be made, by forcing into the way of the electric matter, part of he vapours of the air.

The claps of Thunder which accompany the flashes of Lightning, seem to be occasioned by the filling of the vast vacuum made by the passage of he electric matter: for, although the air collapses he moment after the matter has passed, and the vibration on which the sound depends commences at he same moment: yet when the flash is directed owards the person who hears the report, the vibrations excited at the nearer end of the track, will each his ear much sooner than those from the remote end; and the sound will, without any echo or repercussion, continue, till all the vibrations have uccessively reached him.

It must be confessed, however, that the question, ow it happens that particular parts of the earth or he clouds come into the opposite states of positive nd negative electricity, is not absolutely determined:

among the numerous conjectures, the one which supposes the electric matter then in the clouds to be generated by the fermentation of sulphureous vapour with mineral or acid ones, seems to have a great share of probability, especially when it is recollected that Thunder-storms generally happen when the ai is in a sultry state.

With regard to the degree of danger in storm of Thunder and Lightning, it is not easy to speak with precision: though it may be noticed, that i seems to depend chiefly on the distance from th track of the electric fluid: which distance is great or less in proportion as a greater or less interval time elapses, between seeing the flash and hearing the explosion.

As to places of safety from the danger of the storms, the general opinion is that the open fiel are more safe than under cover of a house: tho who are in the fields at such times, would do we to place themselves within 50 yards of a tree, b by no means, quite near it. It is generally thoug safer to have one's clothes wet than dry, as t Lightning might then in a great measure be tran mitted to the ground, by the water on the outsi of the body.—Under cover, people are advised sit near the middle of a room on one chair, a lay the feet on another, observing that no me as candlesticks, iron chains, &c. are near. A s better method is, to place the chairs upon mattre or feather-beds: a safer way yet is, to be in a ha nock hung on silken cords at an equal distance rom all the sides of the room. But the place of reatest safety must be in a deep cellar, and especially the middle of it; for when a person is lower han the surface of the earth, the Lightning must trike it and spend itself, having a great probability of not reaching him.

A building may be secured to a considerable degree, from the dreadful effects which Lightning ometimes produces; and this by fixing a pointed ron rod higher than any parts of the building, and oining to the lower end of it a wire which must communicate with the earth, or rather, the nearest water. This rod the Lightning will seize upon, ooner than any part of the building; it will therefore descend along it, and the annexed wire, till it eaches the earth or water, when it will be dissipated without doing any harm. It would be advisable to have that part of the wire which is within ive or six feet of the ground, surrounded by an open frame, of such a kind as will prevent men or nimals from coming so near the wire, as to be injured by the Lightning, which it is designed to convey to the earth.

Several of the British poets and poetesses have iven us sublime descriptions of Thunder-storms, with admirable reflections thereon: as a specimen, my young readers are requested to peruse the following.

In gloomy pomp, whilst awful midnight reigns,
And wide o'er earth her mournful mantle spreads,
Whilst deep voic'd Thunders threaten guilty heads,
And rushing torrents drown the frighted plains,
And quick-glanc'd Lightnings, to my dazzled sight,
Betray the double horrours of the night:

A solemn stillness creeps upon my soul,
And all it's powers in deep attention die;
My heart forgets to beat; my stedfast eye
Catches the flying gleam; the distant roll,
Advancing gradual, swells upon my ear
With louder peals, more dreadful as more near.

Awake, my soul, from thy forgetful trance!
The storm calls loud, and meditation wakes;
How at the sound pale superstition shakes,
Whilst all her train of frantic fears advance!
Children of darkness, hence! fly far from me!
And dwell with guilt and infidelity!

But come, with look compos'd and sober pace,
Calm Contemplation, come! and hither lead!
Devotion, that on earth disdains to tread;
Her inward flame illumes her glowing face,
Her upcast eye, and spreading wings, prepare
Her flight for heav'n to find her treasure there.

She sees, enraptur'd thro' the thickest gloom,
Celestial beauty beam, and 'midst the howl
Of warring winds, sweet music charms her soul;
She sees while rifted oaks in flames consume,
A FATHER GOD, that o'er the storm presides,
Threatens, to save,—and loves, when most he chides.

Mrs. CHAPON

LESSON XXIII.

ON THE IGNIS FATUUS.

> ——————A wand'ring fire
> Compact of unctuous vapour, which the night
> Condenses, and the cold environs round,
> Kindled thro' agitation to a flame,
> (Which oft, they say, some evil spirit attends,)
> Hovering, and blazing with delusive light,
> Misleads th' amaz'd night-wanderer from his way
> Thro' bogs and mire. MILTON.

TOO numerous by far are the stories of ghosts nd apparitions, hobgoblins and spectres, which are anded down from one generation to another, by e great weakness and folly of some parents and irses, whose whole intention one would imagine , to make their children chiefly susceptible to the npressions of fear. When we consider how diffiult it is to eradicate prejudices which were imbibed childhood, we shall not be greatly surprized at e avidity with which tales of the mischievous feats erformed by *Jack o'Lanthorns*, and *Will with a Visps*, are swallowed, even by upgrown people, f mature judgment in other concerns. For instance, child may have been told by his father, that once when going over a piece of marshy land in a dark night, he was suddenly startled with the appearance of a spirit wrapped up in fire, which kept dancing round him, and dazzled his eyes to such a degree, that he became dismally frightened, and so the fiery spirit led him out of his road, and then left him. This misfortune of the father would be remembered by the child when he arrived at years of maturity, when he would perhaps hear several similar tales from other persons, which the credulous youth would look upon as so many corroborating testimonies of the reality of such ghostly appearances; and, of course, the prejudice would be the more firmly rooted in his mind.

Should any persons who have been thus miserably misinformed, peruse these Lessons, I hope they will be quickly convinced that these horrible *Jack o'Lanthorns*, are far from having any thing supernatural about them: on the contrary their causes, and the effects they produce, may be accounted for in a very natural and easy manner.

The meteor vulgarly known by the names before mentioned, is among philosophers called *Ignis Fatuus*; it is chiefly seen about marshes, meadows, and other moist places, also in burying grounds that lie flat and low, and sometimes near dunghills. The appearances of it usually observed, sufficiently evince that it is an ignited vapour: for inflammable air has been found to be the most common of all the factitious airs in nature; and as it is known to be freuently produced from the putrefaction and decomosition of vegetable substances in water, with hich marshes, bogs, &c. abound, it may be reaonably inferred that when this inflammable air ises, it will be speedily kindled, and being wafted bout near the surface of the earth, will cause the ppearances which create so much unnecessary alarm.

The celebrated Dr. *Shaw* has described a remarkle Ignis Fatuus which he saw in the holy land, hen the atmosphere had been thick and hazy, inmuch that the dew on the horses bridles was rearkably clammy and unctuous. This meteor was ometimes globular, then in the form of the flame f a candle; presently afterwards it spread itself so uch as to involve the whole company in a pale rmless light, and then it would contract itself and ddenly disappear. But in less than a minute it ould become visible as before, or running along om one place to another, with a swift, progressive otion, would expand itself at certain intervals over ore than two or three acres of the adjacent mounins.

In the plains in the territory of Bologna, these eteors are very often seen: sometimes they vary figure and situation in a very uncertain manner; t commonly they are very large, and give a light qual to a torch.

Even in England they are frequently seen in diferent numbers from two or three to upwards of wenty together in one ground, running here and there with great rapidity: sometimes mixed togeth and crossing each other's paths, as though the were dancing; then all at once several of the disappear, which may perhaps be occasioned b their striking against each other, or some contiguo object. In many places, one may be almost su of seeing them every dark night.

That persons should be led out of the way b these meteors is more to be attributed to their ow unreasonable fears, raised by prejudices instilled in their minds in their infantile years, than any oth cause. For when the Ignis Fatuus happens t overtake or approach them, they are struck wi fear and surprize at so shining a light, and dism spectre, as they imagine it to be; whence they i their fright immediately run out of the direct pat way, and by such deviation very probably lose the road entirely: more especially, if (as will most fre quently be the case) the meteor be attracted aft them in their flight.

From a consideration of what has been here ad vanced, the great importance of being educa without having any superstitious or childish preju dices engrafted in the mind, is exceedingly obviou to the elder part of my readers I would therefo take the liberty of recommending a peculiar at tention that no idle trash be insinuated into th minds of their children; for in this, as well as oth cases,

Children, like tender osiers, take the bow,
And as they first are fashion'd always grow.

DRYDEN.

To those who have, unfortunately, been badly
ucated in this respect; a friendly act would be,
endeavour with sound reasoning to convince them
their errour, and dissuade them from giving heed
future, to idle, superstitious or inconsistent stories
any kind; advising them to furnish themselves
ith such knowledge, as may have a tendency to
oduce true pleasure and happiness through life;
d which when dying they can reflect upon with-
t uneasiness *.

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* "The natural offspring of prevailing superstition is infidelity.
the truth of this, the present times afford us a lamentable ex-
ple. Where ignorance and fear once ruled supreme, there has
h philosophy but too successfully planted presumption and
cism. 'Tis the diffusion of pure and solid knowledge, which
ne can preserve us from the dominion of these opposite tyrants.
w should this consideration increase our zeal and stimulate our
eavours! The immediate sphere of our action may be circum-
bed, but our exertions will not on that account be entirely lost.
that circumscribed sphere let us labour to root out every su-
stitious lying vanity, and plant pure religion and unsophisti-
d truth in its stead.

" How charming, how enlivening to the soul, to gaze upon
dawning beams of opening light, to behold them irradiate that
al gloom of intellectual darkness, which long overwhelmed
millions of mankind: how supremely pleasing, to view them
er and wider spreading their invigorating influence: how rap-
usly transporting, to contemplate the splendescent prospect
ure and perfect day!

"Power supreme!
"O everlasting King! to thee we kneel,
"To thee we lift our voice;"—

"O spread thy benign, thy vivifying light over the dwellin of the sons of men; dispel the yet impending mists of ignoran and superstition: and, O preserve us from the dismal gulph o infidelity and atheism; let thy truth run and prevail gloriously let pure, celestial wisdom overspread the earth as the waters cov the sea!—Then shall millions kneel before thee with grateful an enraptured hearts; then shall they rejoice to sing the praises o thee, their Benefactor, their Father, and their God: then shal this vale of tears be filled with the mansions of joy and gladne and become a blissful foretaste of those regions, where thy sain crowned with unfading glory and felicity, surround thy thro with never-ceasing hallelujahs!"

See Sermons on "*The Inanity and Mischief of Vulgar Supe- stitions*," by the Rev. *M. J. Naylor*.

LESSON XXIV.

ON THE AURORA BOREALIS.

—Silent from the north,
A blaze of meteors shoots: ensweeping first
The lower skies, they all at once converge
High to the crown of heav'n, and all at once
Relapsing quick, as quickly reascend,
And mix and thwart, extinguish and renew,
All æther coursing in a maze of light. THOMSON.

THERE are, perhaps, but few appearances in
ture which are more curious than those known
the appellations, *Aurora Borealis*, *Northern-*
hts, or *Streamers*: the radiant streams, like le-
ons rushing to the engagement, meet and mingle;
omuch that the air seems to be conflicting fire:
presently, they start from one another; and like
nies in precipitate flight, each marching a dif-
ent way, they are thrown into a quivering mo-
n:—the whole horizon is illuminated with the
ncing flames; and with an aspect partly awful,
l partly ludicrous, they represent extravagant and
ic vagaries.

The villagers assembled together, gaze at th spectacle, first with astonishment, then with horrour:

> From look to look, contagious thro' the crowd
> The panic runs, and into wond'rous shapes
> Th' appearance throws: armies in meet array,
> Throng'd with aërial spears and steeds of fire,
> 'Till the long lines of full extended war,
> In bleeding fight commixt, the sanguine flood
> Rolls a broad slaughter o'er the plains of heav'n.
> As thus they scan the visionary scene,
> On all sides swell the superstitious din,
> Incontinent, and busy frenzy talks
> Of blood and battle, cities overturn'd,
> And late at night in swallowing earthquake sunk
> Or hideous wrapt in fierce ascending flame;
> Of sallow famine, inundation, storm;
> Of pestilence, and very great distress;
> Empires subvers'd, when ruling fate has struck
> Th' unalterable hour: ev'n nature's self
> Is deem'd to totter on the brink of time. THOMSON.

Though this waving brightness which plays innocently over our heads causes such astonishment in the gazing throng; it has a very differe effect upon the philosopher: he feels stimulated t enquire how so curious, and in great measur pleasing an appearance may be occasioned. I order to arrive at the result of such enquiry, it w be necessary to consider with attention the vario phenomena of this meteor as they have been curately observed.

It may be observed, then, that the appearances
the *Aurora* come under four different descrip-
ns.—First, a *horizontal light* like the morning
urora, or break of day: which horizontal light
ds to the magnetic east and west, and is bisected
the magnetic meridian.—Second, fine splendid,
minous *beams*, well defined, and of dense light;
ese continue ¼, ½, or 1 minute, sometimes appa-
ntly at rest, but more frequently with a quick
eral motion: these *beams* appear at all places
ke, to be arches of great circles of the sphere,
th the eye in the centre, and these arches if
olonged upwards would all meet in one point;
s converging point is the same as that to which
e south pole of the *dipping needle* points, at the
ce where the observation is made.—Third, *flashes*
inting upward, or in the same direction as the
ams, which they always succeed; these are only
omentary, and have no lateral motion, but they
e generally repeated many times in a minute;
ey appear much broader, more diffuse, and of a
aker light than the beams; they grow gradually
nter till they disappear, but they sometimes con-
ue for hours, flashing at intervals.—Fourth,
ches nearly in the form of rainbows; these,
en complete, go quite across the heavens, tend-
g to the magnetic east and west, and crossing
e magnetic meridian at right angles.

When an *Aurora* takes place, the appearances
ove described, generally succeed one another in

the following order:—first, the faint, rainbow- arches; second, the beams; third, the flashes: for the horizontal light, it is found to consist of abundance of flashes or beams, blended togeth owing to the situation of the observer relative them.

These phænomena have been accounted for various suppositions. 1. It has been supposed be a flame arising from a chymical effervescence combustible exhalations from the earth. 2. It h been thought to be inflammable air, fired by el tricity. 3. It has been imagined to be occasio by the zodiacal light. 4. It has been conjectu that it is caused by the reflection of the sun's be on large bodies of ice floating near the polar regi But all these suppositions will admit of objectio being utterly inadequate to account for the pearances. Lastly, it has been supposed *elec light* itself; and this opinion has met with m advocates since the identity of lightning and electric matter has been determined: for we kn that discharges of the electric fluid in the atm phere do exhibit light; and for this and other r sons which might be advanced, it is considered most beyond a doubt, that the *light* of the *Au Borealis*, as well as that of *falling stars*, and *larger meteors*, is *electric light* solely, and t there is nothing of combustion in any of th phænomena.

Mr. *John Dalton*, in the treatise which I men-
ned in the seventeenth Lesson, has handled this
bject in a very curious and philosophic manner:
has proved, from mathematical demonstrations,
t the luminous beams of the *Aurora Borealis* are
lindrical, and parallel to each other, at least,
er a moderate extent of country: he also ob-
ves, that these beams are all magnetic; and in-
ed he gives very conclusive reasons to shew,
t the phænomenon we are speaking of is a mag-
ic one, and that its beams are governed by the
th's magnetism.

Part of the reasoning of this very ingenious gen-
man I shall here make use of; referring the reader,
more on the subject, to the book itself. "We
under the necessity of considering the beams of
Aurora Borealis of a ferruginous nature, be-
se nothing else is known to be magnetic, and
nsequently, that there exists in the higher regions
the atmosphere an elastic fluid partaking of the
perties of iron, or rather of magnetic steel, and
t this fluid, doubtless from its magnetic property,
umes the form of cylindric beams. It should
m too, that the rainbow-like arches are a sort of
gs of the same fluid, which encompass the earth's
thern magnetic pole, like as the parallels of la-
de do the other poles; and that the beams are
nged in equidistant rows round the same pole.
first view, indeed, it seems incompatible with
known laws of magnetism, that a quantity of

magnetic matter should assume the form of su rings, by virtue of its magnetism; but it may ta place in one case at least, if we suppose the rings tuate in the middle, between two rows of beams, that the attraction on each side may be equal. for the beams, in their natural state, when not act upon by causes hereafter to be mentioned, th must all be guided by the *earth's magnetism* mean the cause that guides the needle, whether be in the earth or air, I know not,) and con quently all have their *north poles* downward; whether any two neighbouring beams have the p of the same denomination, or of different deno nations, acting upon each other, still the effect be the same, and their mutual action upon ea other will not disturb their parallelism, nor the p sition of the rings; because, whether the poles tually attract or repel each other, it is of no ment in this case, and the attraction of each pole alike upon the rings."

" Things being thus stated, I moreover supp that this elastic fluid of magnetic matter is, like pourized air, an *imperfect conductor* of electri and that when the equilibrium of electricity in higher regions of the atmosphere is disturbed, conceive that it takes these beams and rings as c ductors, and runs along from one quarter of heavens to another, exhibiting all the phænom of the *Aurora Borealis*."

LESS

LESSON XXV.

ON LIGHT AND COLOURS.

Behold the Light emitted from the sun;
What more familiar, and what more unknown?
While by it's spreading radiance it reveals
All nature's face, it still itself conceals.

BLACKMORE.

God said,—let there be Light:—and there was Light.

MOSES.

HE famous *Longinus*, in his treatise on the
lime in writing, produces the above passage of
inspired historian, as one of the most beautiful
had ever met with. The chief beauty of it
ns to consist in a striking declaration of the al-
hty power of God: from this passage alone
might infer, that to will, to speak, and to ac-
plish, is all one with the Deity; being an
ntial part of his attributes, without which he
ld be imperfect. In the *sacred record* it is next
, that "God saw the *Light*, that it was good:"
indeed *we* have the greatest reasons for thinking
How good must that Light be, which enables
behold the heavens beautified with stars; and

by means of which we can look around us, and trace the numerous wonders of the earth we inhabit, raising in our minds the most exalted ideas of the divine perfections! We may also here observe, that the all-wise CREATOR has so divided our time into day and night, Light and darkness, that we may never forget that all things in human life are mixtures of good and evil. Heaven is said to be all Light, and hell is as frequently represented to be utter darkness: wherever the favour of God shines, there is light;

> ——— "His presence gives eternal day,
> And makes eternal rest:"

but his absence and anger create darkness.

By *Light*, I would wish to have understood, th principle by which objects are made perceptible our sense of seeing; or the sensation occasioned the mind by the view of luminous objects. T nature of Light has very long been a subject philosophical speculation: the earliest philosoph doubted whether objects became visible by means any thing proceeding from them, or from the of the spectator. On this subject, opinions still afloat. It is thought by some, that Light m be a fluid *(per se)* equally diffused through universe; the action of the solar, or other rays, necessary, according to this hypothesis, to gi motion, and make its effects perceptible. O are of opinion that Light is a *quality*, which ca

xist independently of matter, and which requires
e assistance of the solar and other rays, to bring
into action. But as the hypothesis of *Newton*
the most generally received, what I shall say on
e subject will be agreeable thereto; though it
ust be allowed that some formidable objections
ve been advanced against it.

The Newtonians maintain, that Light consists of
great number of exceedingly small particles,
rown off from the luminous body by a repulsive
wer with an immense velocity, and in all direc-
ons; hence, Light is produced from motion: but
en as all motion will not produce Light, there-
re much manifestly depends on the quality of cer-
in bodies which are of themselves luminous, and
ve the constant and invariable property of emitting
sending forth these very minute particles: such
the property of the sun, a star, a candle alighted,
d all sorts of flame, &c. The velocity of the
rticles of Light is truly astonishing, amounting to
ar two hundred thousand miles in a second of
ne, which is near a million times greater than
velocity of a cannon ball: this may be easily
oved by observations on the eclipses of Jupiter's
tellites; for when the earth is between the sun
d this planet those eclipses will happen about 8¼
nutes sooner, than according to the tables; but
hen the earth is in the contrary position, the
lipses happen about 8¼ minutes later than they
predicted by the tables. Hence, therefore, light

takes up about 8¼ minutes in passing from the sun to the earth, a distance of 95 millions of miles; whence what was just above-mentioned may be deduced.

Since Light spreads itself every way with such incredible velocity, it is evident that if its particles were not surprisingly small, it would strike against bodies with great force; this would be very injurious to those tender organs the eyes, and would probably soon cause blindness: but it is found that these particles are small, almost beyond conception; for it has been computed that there fly out of the end of the flame of a burning candle in a second of time, ten thousand millions of times more such particles, than there are visible grains of sand in the whole earth: if they were not inconceivably small, it is certain therefore that the flame would be entirely vanished.

It is also asserted, that the particles of Light are emitted in right lines: which rectilinear motion they preserve, till they are turned out of their path by some of the following causes: viz. either by the attraction of some other body near which they pass, which is called *inflection;* or, by passing obliquely through a body of different density, which is called *refraction;* or, by being turned aside by the opposition of some intervening body, which is called *reflection;* or, lastly, by being totally stopped by some body into which they penetrate, and this is called their *extinction.* A succession of these p

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ticles following one another, in an exact right line, is called a *ray of Light*; and this ray, in whatever manner its direction may be changed, whether by eflection, refraction, or inflection, always preserves a rectilinear course, till it be again changed. It is o be observed, that bodies, as they respect the rays of light, are divided into three kinds: 1. Those which *emit* the rays of Light; as the sun and fixed tars: 2. Those which *transmit* the rays; as the ir, and glass: and 3. Those which *reflect* them, as the moon, the earth, polished iron, &c. The irst are called *luminous*, the second *pellucid*, and he third *opaque* bodies. It is also to be observed, hat the rays of Light themselves are not seen; but by their means we see the luminous bodies, from which they originally came, and the opaque bodies, rom which they are reflected: thus, for instance, when the moon shines, we cannot see the rays which pass from the sun to the moon; but, by their means, we see the moon, from whence they are eflected. If the eye be placed directly in the medium, through which the rays pass to it, the medium is not seen; thus, we never see the air through which the rays come to our eyes. But if a pellucid body, through which the rays are to pass, be placed at a distance from our eyes, that body will be seen, as well as those bodies from whence the rays come which pass through it to our eyes. For instance, he who looks through a pair of spectacles, not only sees bodies through them, but also sees the spectacle glasses; because the glass, being a solid body, reflects some rays of light from its surface; and being placed at a convenient distance from the eye, may be seen by those reflected rays, at the same time that bodies at a greater distance are rendered visible by the transmitted rays.

The properties of reflection and refraction produce several curious effects, some of which have been noticed in the sixteenth Lesson; and others will be spoken of as we proceed.

Amongst them we must not pass by the phænomenon of the variety of *Colours,* which are observable all over the face of nature, seeming peculiarly adapted to increase the pleasure of mankind. *Colours* are nothing else than different sensations excited in us by the variously refracted rays of light being carried to our eyes in a different manner, according to the different size, or shape, or situation of the particles of which the surfaces of bodies are composed. Colours then, are not inherent in the bodies which appear to wear them; but they seem to arise from a capability or disposition in those bodies to reflect back particular rays, and these rays possessing different degrees of refrangibility produce the effect: thus it is found that the least refrangible rays produce the idea of a red Colour, and as the refrangibility increases, the ideas of the intermediate Colours are excited, till at length we arrive at the opposite extreme of refrangibility, and then the sensation of a *violet* Colour is produced.

The primary Colours are, according to NEWTON, seven in number, of these I here present you with a poetical account:

————First the flaming *red*
Sprung vivid forth; the tawny *orange* next;
And next delicious *yellow*; by whose side
Fell the kind beams of all-refreshing *green*;
Then the pure *blue*, that swells autumnal skies,
Etherial play'd; and then, of sadder hue,
Emerg'd the deepen'd *indico*, as when
The heavy-skirted evening droops with frost;
While the last gleamings of refracted Light
Dy'd in the fainting *violet* away. THOMSON.

Thus you have the regular gradations from one Colour to another laid before you, agreeably to the hypothesis which supposes the number of primary Colours to be seven: but it is yet a matter of dispute whether there are *seven* primary Colours, or whether their number is greater or less than seven. Many persons assert that there are but *three primary* Colours; but it is very evident that they affix an idea to the term totally different from that which is derived from *Newton's* definition. He calls the Light whose rays are all alike refrangible, *simple*, *homogeneal*, and *primary*: and he shews that *Colours may be produced by composition, which shall be like to the Colours of homogeneal Light, as to the appearance of Colour, but not as to the immutability of Colour and constitution of Light.* But the new opinion of the theorists above spoken of is, that the primary Colours are *red*, *yellow*, and *blue*, because, of proper mixtures of these three Colours, all others may be formed;—it would be a needless multiplication of words to shew, that Newton and they considered the subject in different points of view.

To have a familiar notion of the production of Colours, let the following experiment be tried: any time when the sun shines, standing in the open air, let the bowl of a tobacco-pipe be filled with a lather of soap and water; then, gently blowing at the other end, a large bubble will arise, which let remain suspended at the top of the bowl: then let two or three persons carefully observe the different Colours, as they arise in the bubble; and they will perceive first *red*, then perhaps *blue*, or *orange*, *green*, *indico*, *violet*, and in short, here and there, all manner of Colours; even *white*, and perhaps at last a sort of *black* *.

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* The following curious and useful remarks on the differen degrees of heat imbibed from the sun's rays, &c. by cloths of different Colours, were extracted from "Experiments and Observations" by that famous American philosopher and politicia *Dr. B. Franklin.*

"First, let me mention an experiment you may easily mak yourself. Walk but a quarter of an hour in your garden wh the sun shines, with a part of your dress white, and a part black; then apply your hand to them alternately, and you will find a very great difference in their warmth. The black will be qui hot to the touch, the white still cool."

"Anoth

It may be observed, that *black* and *white* are never reckoned among the primary Colours; for *black*

" Another. Try to fire paper with a burning glass. If it be white, you will not easily burn it;—but if you bring the focus to a black spot, or upon letters written or printed, the paper will immediately be on fire under the letters."

" Thus Fullers and Dyers find black cloths of equal thickness with white ones, and hung out equally wet, dry in the sun much sooner than the white, being more readily heated by the sun's rays. It is the same before a fire; the heat of which sooner penetrates black stockings than white ones, and is so apt sooner to burn a man's shins. Also beer much sooner warms in a black mug set before the fire, than in a white one, or in a bright silver tankard."

" My experiment was this: I took a number of little square pieces of broad cloth from a Taylor's pattern card, of various colours. There were black, deep blue, lighter bue, green, purple, red, yellow, white, and other Colours, or shades of Colours. I laid them all out upon the snow in a bright sunſhiny morning. In a few hours (I cannot now be exact as to the time) the black being warmed most by the sun, was sunk so low as to be below the stroke of the sun's rays; the dark blue almost as low, the lighter blue not quite so low as the dark, the other colours less as they were lighter; and the quite white remained on the surface of the snow, not having entered it at all."

" What signifies philosophy that does not apply to some use? May we not learn from hence, that black clothes are not so fit to wear in a hot sunny climate, or season, as white ones; because, in such clothes the body is more heated by the sun when we walk abroad, and are at the same time heated by the exercise, which double heat is apt to bring on putrid dangerous fevers? That soldiers and seamen who must march and labour in the sun, should, *black* cannot with propriety be called a Colour, it being a deprivation of all Light, because the substance stifles all the rays: but *white*, on the contrary, is comprehended of all the primary Colours in one, as may be proved experimentally, by taking a small wheel with a broad rim, which let be divided into 360 equal parts; then let 45 of these parts he painted *red*; 27, *orange*; 48, *yellow*; 50, *green*; 60, *blue*; 40, *indico*; and 80 of *violet*;

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should, in the East or West Indies have an uniform of white? That summer hats for men or women, should be white, as repelling that heat which gives head-achs to many, and to some the fatal stroke that the French call the *Coup de Soleil*? That the ladies summer hats, however, should be lined with black, as not reverberating on their faces those rays which are reflected upwards from the earth or water? That the putting a white cap of paper or linen, within the crown of a black hat, as some do, will not keep out the heat, though it would if placed without? That fruit walls being blacked may receive so much heat from the sun in the day time, as to continue warm in some degree, through the night, and thereby preserve the fruit from frosts, or forward its growth? With sundry other particulars of less or greater importance, that will occur from time to time to attentive minds?"

Many other properties of bodies of different Colours, may be found in various parts of *Sir Isaac Newton*'s optics.

The subject of Light and Colours has been lately considered with much acuteness and attention by Mr. *Delaval*. From a variety of well conducted experiments this gentleman concludes, that Colours are exhibited, not by reflected, but by transmitted Light. For an ample investigation of this curious and interesting subject, the reader must be referred to the *Memoirs of the Manchester Society*, Vol. II.

making in all 360: if this wheel be whirled swiftly round, the rim will appear as though it were painted f the purest *white.* It is pretty generally admitted hat the whiteness of the sun's Light is owing to a nixture of all the original Colours in a due proporion; and hence it is naturally concluded, that whiteness in other bodies is a disposition to reflect all the ays of Light in the same proportion and order as hey come from the sun.

My young readers will, I doubt not, after attendng to what has been advanced in this Lesson, readily nite with me in acknowledging with gratitude and oy, the great utility and benefit of Light. For by he help of this admirable, this first made creature f the *Deity*, we are enabled (as before suggested) o behold many other of his glorious works: we can iew with admiration and pleasure the beauties of he flowery fields, the gay attire of the feathered ibes, the exquisite and well adapted proportions of nany insects, quadrupeds, and other creatures; we an dwell with rapture in the contemplation of exnsive landscapes and diversified prospects; we can ace enough to be convinced of the great harmony nd beauty of the lower part of creation; and we n extend our views to the heavens, and thus surey God's wonderful skill and contrivance so clearly anifested in every part of his great workmanship.

LESSON

LESSON XXVI.

ON THE RAINBOW.

———Refracted from yon eastern cloud,
Bestriding earth the grand etherial bow
Shoots up immense, and every hue unfolds,
In fair proportion running from the red,
To where the violet fades into the sky. THOMSON.

DOUBTLESS you have frequently beholden that beautiful appearance known by the appellation of the *Rainbow* or *Iris;* and have observed it bending across the sky in a graceful and majectic figure, painting the arched vault with a pleasing variety of beautiful colours: when this is viewed by the philosophic eye, it immediately stirs up an inclination to search for the cause of so curious and pleasing a phænomenon.

———Not so the playful boy;
He wondering views the bright enchantment bend,
Delightful, o'er the radiant fields, and runs
To catch the falling glory; but, amaz'd,
Behold th' amusive arch before him fly,
Then vanish quite away. THOMSON.

By a perusal of holy writ you will discover, that the *Rainbow* was first placed, and is still at times seen in the clouds, as a pledge of inviolable fidelity and infinite mercy; assuring us that, "While the "earth remaineth, seed-time and harvest, and cold "and heat, and summer and winter, and day and "night, shall not cease." How gracious and benevolent must that Being be, who so often renews a covenant of kindness and mercy to his creatures; and that too, in such a manner as to raise pleasing sensations in every heart, and charm every beholder!

To account for the production of the *Rainbow*, we are in the first place to consider, that it is never seen but in the time of rain, or near it; and when the sun shines. You will understand then, that when a ray from the sun falls upon a drop of rain in a cloud, if it enter the upper part of the drop in a proper situation, it will, by refraction be thrown upon the inner surface of the back part of the drop; from thence it will be reflected to the lower part of the drop, at which place undergoing a second refraction, it will be bent towards the earth: and thus rays of the sun, after one reflection, and two refractions, may come to the eye of a spectator, whose back is towards the sun, and his face towards the drop. When rays which are effectual, emerge from the drop after one reflection and two refractions, those which are most refrangible, will at their emersion, make angles with the incident rays, different from those which are least refrangible; by which means the rays which produce the sensations of different colours will be separated from one another. Hence it may be easily perceived, that some of the falling globules may be in that position which will cause the rays that produce a red colour to fall upon the eye,—others next to them below will send forth orange-making rays,—the drops next to them will cast the yellow-making rays,—and those successively in order below them, will refract the blue, indico, and violet-making rays to the eye;—and thus, in a certain space in the cloud, all the colours will appear: and since, under the same angles, the same phænomena will be produced, therefore an arch of this various coloured light must necessarily be produced in the clouds.

The different sizes of the Rainbows depend entirely upon the height of the sun at the time: for when the sun is in the meridian, or highest altitude, the bow will then be least to our sight, being but a small segment of a circle; but as the sun gets lower and lower, the bow will increase in height; and when the sun is in the horizon, or just setting, a bow at that time is as large as it can be, being very nearly semicircular.

With regard to the part of the sky in which a Rainbow appears, when I say that it is *always opposite to the sun*, I present you with an invariable rule where to find it: and this is an additional reason for concluding, that the appearance is occasioned by the rays of the sun shining upon the falling drops of rain.

There is also often seen a fainter coloured bow, commonly called a *water-gall*, above the Rainbow; and here it will be found, that the colours are in a contrary position to what they are in the bow itself: hence it is evident, that this is a kind of reflection from the Rainbow, or a double reflection from the drops of rain; and as a considerable quantity of light is lost at each reflection, it is plain that the colours in the superiour bow will be more dilute and faint than those in the lower.

The nature of the Rainbow as here explained, may be illustrated and confirmed by experiment in several different ways. Thus, for example, hang up a glass globe, full of water, in the sun-shine, and view it in such a posture, that the rays which come from the globe to the eye, may make an angle of about 42°. with the sun's direct rays, and you will see a full red colour in that side of the globe opposite to the sun: and by varying the position so as to make that angle gradually less, the other colours, yellow, green, and blue, will appear very distinctly, in succession, on the same side of the globe. But if, by raising the globe, the angle be made about 50°. there will appear a red colour in that side of the globe which is toward the sun, though somewhat faint; and if, by raising the globe still higher, the angle be made greater, this red will change successively to the other colours, yellow, green, and blue.

Or, the appearances of the Rainbow may be exhibited in a very natural and beautiful manner any day when the sun shines, with the assistance of an *artificial fountain*, or *jet d'eau*, which is an instrument expressly intended to throw up streams of water to a great height; these streams spreading very wide in their upper part, when falling, form a delightful shower of artificial rain: when the fountain is playing, move between it and the sun, at a proper distance from the fountain, until your shadow points directly towards it; then looking at the shower, you will observe the colours of the Rainbow, very vivid and strong,—those of the water-gall very languid and faint,—the gradations of the colours of each in an inverted order: and, what forcibly shews the deceitfulness of vision, the bows appear, notwithstanding the nearness of the artificial shower, to be as far off, and as large, as those which we really see in a natural shower of rain.

A similar bow is often observed among the waves of the sea, the upper parts of the waves being blown about by the wind and so falling down in drops: this is called the *Marine Rainbow*. This appearance is also sometimes seen by moon-light, though seldom vivid enough to render the different colours distinguishable; this is called the *lunar Rainbow*. Rainbows are even sometimes seen on the ground, when the sun shines on a very thick dew. All these are of the same nature, and are produced by the same causes as the common Rainbow *.

When we consider what a wonderful scenery of nature is here displayed; and yet, recollect, that though these variegated beauties are the common objects of vision, how few there are that understand the reason of them, and how much fewer are any ways anxious about them: surely those who think the doctrine of colours, &c. highly worthy of contemplation, and who are aware that the knowledge of their causes is truly adorning to a reasonable mind, ought to be thankful that their natural genius enables them to understand such studies!

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* I cannot forbear adding a note in this place, to state a fact which is not universally known: *a piece of iron when beated assumes all the colours of the Rainbow, before it becomes red-hot.* This extraordinary circumstance, I believe, has not yet been satisfactorily accounted for.

LESSON XXVII.

ON HALOS AND PARHELIA.

As when two suns appear in th' azure sky,
Mounted in phœbus' chariot fierie brighte:
Both darting forth faire beams to each man's eye,
And both adorn'd with lamps of flaming light,
All that behold such strange prodigious sight,
Not knowing nature's work, nor what to weene
Are wrapt with wonder, and with rare affrighte.

SPENSER.

THERE remain yet two appearances caused by the reflection and refraction of light, to be described and accounted for: the first, known by the name of an *Halo* or *Crown*, is very frequently seen without creating any degree of surprize; the other, called a *Parhelion*, *Parhelium*, or *mock sun*, is but very seldom observed, and as it is a curious phænomenon, it is not to be wondered at, that it is, among the common people, considered as portentous: to a description of each of these I shall now proceed.

And first of *Halos*, or *Coronæ*, which are coloured circles, or rather ovals appearing round the face of the *sun* and *moon*, also some of the larger stars, particularly the planet *Jupiter*. Halos round the sun or moon, generally appear oval and excentric to the luminary, having their longest diameter perpendicular to the horizon and extending farther below the luminary than above it; this probably is a deception of vision, arising from the apparent concave of the sky being less than a hemisphere. Those about the moon are often very large, and when seen by the country people, they will commonly observe, " We shall have a change of weather soon, for there is *a bur round the moon*:" perhaps their observation may not be altogether void of a reasonable foundation.

Philosophers sometimes conceive Halos to arise from a refraction of the rays of light in passing through the fine rare vesiculæ of a thin vapour towards the upper parts of the atmosphere. But an opinion more generally received, is that which supposes Halos to be formed by small round grains of hail, composed of two different parts, the one of which s transparent, inclosing the other which is opaque, nd the reflection from these producing the appearnces: this is the more probable when it is recolected that they are only seen in frosty, rhimy, or azy weather.

There are several ways of exhibiting phænomena imilar to those of halos: thus, the flame of a canle, placed in the midst of a steam in cold weather; r placed at the distance of some feet on the other de of the window, in each of these circumstances will appear to be encompassed by a coloured Halo, Also, when the window of a room is encrusted over with a thin plate of ice, the moon seen through it will seem surrounded with a large and various coloured Halo.

Parhelia are far more rarely seen, but their appearance is wonderfully curious: their apparent size is generally the same as the true sun; but they are not always round, nor always so bright as the sun; and when several appear, some are brighter than others. They are tinged externally with colours like the rainbow, and many of them have a long fiery tail, opposite to the sun, growing paler towards the extremity. These tails mostly appear in a white horizontal circle, commonly passing through all the parhelia, and would go through the centre of the sun, if it were entire.

We have on record, an account of Parhelia seen at *Rome,* in March 1629: at this time four were observed, one of which was very much tinged with various colours like the rainbow; and the others more faintly so. Some were also observed by *Cassini,* in 1683. In *England* and *Scotland,* tw have frequently been seen at a time. In *Nort America* they are often seen, and continue f hours, nay sometimes for several days, being visib from sun-rise to sun-set: when these disappear, ra or snow is there generally expected.

M. Huygens, on applying his attention to th appearances, was soon sensible that they could n arise from such globules as formed the *Halos;* f

sin

nce *Parhelia* are always attended with Halos, he
as satisfied that their causes must be much alike.
onsidering, then, what other figures hail-stones
ight possibly have, besides a spherical one, he
uld find no other so simple as that of a cylinder;
d indeed, he had often observed, that snow did
nsist of several slender oblong particles, mixed with
ose of other shapes: and seeing that small globules
ere sufficient for the production of Halos, he
agined that a great number of small cylinders,
ating in the air, might produce similar appear-
ces. He also remembered that *Descartes* had
ken notice of certain small columns, which he had
en lying on the ground, the extremities of which
ere bounded with flat star-like figures, consisting of
x rays.

The large white horizontal circle, observed in
me of these phænomena, M. Huygens supposed
be produced by the reflexion of the sun's rays
om the outsides of the upright cylinders; since,
hen the sun shines upon a number of such cylin-
rs suspended in the air, a white circle must neces-
rily appear to pass through the sun parallel to the
rizon. This he shews very distinctly by a large
ure of a cylinder, and by pointing out the pro-
ess of the sun's rays reflected from it. For every
int of the sun's vertical diameter, as well as his
nter, will illuminate a circle of cylinders, of the
me apparent height as the illuminating point.—It
observable that no thick clouds are seen in the air

when these circles appear; but only such as are very thin, and scarcely visible. For in most of these observations the sky is said to have been very clear and serene; which very well agrees with this hypothesis: since these minute cylinders must constitute a very thin cloud uniformly extended; through which the sun, and even the blue colour of the sky may be seen.

The whole of *Huygens*'s dissertation, from which the above hypothesis is deduced, is much too long to be given in this place: those of my young readers who wish to peruse it, are referred to chap. xii, book 1. Dr. *Smith*'s *Optics*.

LESSON XXVIII.

ON FIRE.

Fire, thou swift herald of his face,
Whose glorious rage at his command,
Levels a palace with the sand,
Blending the lofty spires in ruin with the base.
Ye heavenly flames that singe the air,
Artillery of a jealous God:
Bright arrows that his sounding quivers bear,
To scatter deaths abroad:
Lightnings, adore the sovereign arm that flings
His vengeance, and your fires, upon the heads of kings.

WATTS.

our contemplations we will now make a transi-
, to consider the advantages, nature, and effects,
at wonderful agent of nature called *Fire:* and
we shall find numerous reasons for increasing
ratitude and love to the beneficent POWER who
uced so astonishing an element chiefly for our
If there were no such thing as fire, in what
ld the earth we inhabit, after the setting of
sun, covered with cloudy and nocturnal va-
s, differ from the most dismal subterraneous
ns and dungeons? Since during such time
an would be able to dispatch any kind of busi-
neither would he have the temerity to move

one foot forwards. Without fire, which by the means of candles, lamps, torches, and the like, affords us light in the greatest darkness, what difference would there be between our condition, and that of men who should be blind half their lifetimes? Without fire, greater part of the productions of the earth, which serve mankind for food, for refreshment, or for dainties, would be absolutely unfit for those purposes; as several of them could neither be chewed by the teeth, nor digested by the stomach. Nay, we may be easily convinced, that neither corn, nor flesh, nor several of the fruits of the ground, nor of trees, would, without the help of fire, be of any service; but would turn to a crude unwholesome nourishment.

Again,—would not the dreadful cold of winter, if not moderated by fire, be the mean of dispeopling whole countries, and of freezing to death myriads of men, women, and children? And, again,—if there were no fire, though the mines of iron, &c. were more numerous than they are, of what utility would they be? Since, without its aid, they could not separate the metal from the ore, nor by any means make those instruments for agriculture, arts, and manufactures, which we now have in such abundance.

For the sake of a supposition, let us imagine, that we were in a state, continually without light, without warmth, without any method of preparing raw food for sustenance, without all the conveniences which metals (and principally iron) now affords us: let us suppose, I say, that in such a situation we received information that a person had invented a matter, by the help of which all these defects and wants might be supplied: I would only ask, if we hould not, under such circumstances, entertain very igh ideas of the wisdom of the inventor?

The ingenious young reader will know how to pply this conjecture and question, without any arther comment upon them.

By *Fire* is here to be understood, that subtile invisible cause by which bodies are made hot to the ouch, and expanded or enlarged in bulk; by which luids are rarefied into vapour; or solid bodies become fluid, and at last either dissipated and carried ff in vapour, or else melted into glass. It seems also o be the chief agent in nature, on which animal nd vegetable life have an immediate dependence.

Fire is distinguished into two kinds; as it is in self, called *Elementary Fire*; and as it is joined ith other bodies, called *Culinary Fire*. Fire, *ure* or *elementary*, such as exists in itself, is what e properly call Fire, and has lately been denominated *absolute heat*. Common, or *culinary* Fire, that existing in ignited bodies, or excited by the rmer in combustible matters, the minute particles which joining with the pure Fire constitute *lame*. Some of the effects and properties of each these kinds of Fire, let us now proceed to nsider.

Pure Fire is of itself imperceptible, and onl discovers itself by certain effects which it produc in bodies, which effects are only learnt by observi the changes that arise in those bodies. The fi effect of elementary Fire on bodies is *heat*, whic arises wholly from Fire; and in such manner as th the measure of heat is always the measure of Fir and the measure of Fire is that of heat. Th second effect is *dilatation* in most solid bodies, a rarefaction in all fluids. That both these are i separable from heat, is evident from numerous e periments. An iron rod or bar being heated, i creases in all its dimensions; and the more so as i is farther heated: upon exposing it to the cold agai it contracts, and returns successively through all th degrees of its dilatation, till it arrives at its first bul The like is observed to take place in the heaviest o all bodies, gold, which when fused takes up mo space than before; and mercury, the heaviest o fluids, has been known to ascend in a narrow tub over the fire, to above thirty times its height.

The laws of this expansion are, 1. That th same degree of Fire rarefies fluids sooner, and in greater degree than it does solids. 2. The ligh the fluid, the more it is dilated by Fire. Thus ai the lightest of all known fluids, expands the mo and next after air, spirit of wine. Certain mat are so much rarefied by even a moderate heat, t they seem to lose all their specific gravity, or b come, at least, specifically lighter than all surro ing bodies; hence these substances, when heated to a certain degree, are raised as bodies would be without gravity. Substances which have this property are called in general *volatile substances.* Other bodies are so little dilatable by Fire relatively to heir density, that the greatest heat which can be iven them produces scarcely any sensible diminuion of specific gravity: these, being almost unlterable in this respect by Fire, are called *fixed ubstances.*

The third effect of Fire on bodies, is *motion*; for ire, in warming and dilating bodies, must of ne-essity move their parts. Upon the absence of only certain degree of Fire, all oils, fats, waters, wines, les, spirits of wine, vegetables, and animals, be-ome hard, rigid, and inert; and the less the degree f Fire, the sooner and more violently is this in-uration made. Hence, if there were the greatest egree of cold, and all Fire were absolutely taken way, all nature would be converted into one con-ete body, solid as gold, and hard as diamond; but pon the application of Fire, it would recover its rmer mobility: consequently, every diminution of re is attended with a proportionable diminution of otion, and the contrary.

All the above-mentioned effects of elementary re, may be increased various ways: First, by *ttrition*, or a swift agitation or rubbing of one dy against another. This is apparent in solids; a olent attrition of a flint and steel, it is well known, will produce sparks: and Fire may be produced with great facility, by the vehement rubbing together of two pieces of dry soft wood. So also i fluids, cream by long churning, to separate the butter, will grow warm by insensible degrees. *Boerhaave* is of opinion, that all the heat of an anim is owing to the agitation and attrition of the par of its juices against each other, and against the side of the vessels.

The second manner of increasing the effect o pure Fire, is, by throwing a quantity of moist o green vegetables, cut down while full of sap, in a large heap, and pressing them close down, th result of which is, that they grow warm, then he they next begin to smoke, and finally will brea out into Flame.

The third way is, by the mixture of certain co bodies. Thus, for instance, take two drams strong and fresh spirit of nitre prepared with oil vitriol, and putting it in a clean and dry gallip set it under a chimney; then put to it at once, the oil of cloves one dram, there will be produ immediately a loud noise and a considerable flam A similar effect may be produced from dry bodie thus, pure sulphur and steel-filings well ground, a mixed in equal quantities, with water sufficient make them into a dry paste, and laid an hour or t any where, even under ground, will smoke and e flame.

T

The fourth method of increasing the effects of pure Fire, is by *Phosphorus*, which is a kind of Fire magnet, prepared from the parts of animals, which imbibes and retains Fire for many years.

But in whatever manner Fire is collected or increased in bodies, upon a cessation of the collecting cause, it soon disappears again, unless it be supplied with a *pabulum* or *fuel;* and in this case it becomes *culinary Fire.*

By *Pabulum*, or *fuel* of Fire, is meant whatever receives and retains Fire, and is consumed, or at least rendered insensible thereby. The only pabulum in nature is the phlogiston of bodies; and bodies are only fuel on account of the oil or phlogiston they contain. Oil and sulphur were names which the ancient chymists gave indiscriminately to substances, into the composition of which a great quantity of what the modern chymists call *phlogiston* enters.

Hence, all vegetables, not too moist, nor too dry, afford such a pabulum; particularly, those which contain the greatest quantity of oil, as balsamic and resinous woods.—All vegetable and animal coals are a proper pabulum for the maintaining of Fire, as being only the parts of vegetables and animals, which have exhaled their water and salt, and retained the oil alone, inhering in a black form in their earth.—All fossil and bituminous earths and turfs; all mineral sulphurs, whether pure, or joined with earth, stone, or metals, as pit-coal, &c. the fat and dung of animals; and several productions of chymistry, as oils and inflammable spirits, afford also a proper pabulum of Fire.

The Fire which burns combustible bodies, requires air to sustain it; which taken away, the Fire is immediately dissipated; as appears from experiments *in vacuo:* except in the case of substances into the composition of which nitre enters; for these will burn *in vacuo*, in fixed air, and under water, as is evident in some rockets which are made for this purpose.

Shining or luminous Fire, seems to be elementary Fire, attracted towards the part of the sulphur or oil, with such force and velocity, as to move and shake them very violently, divide and attenuate them, and thus render them volatile, and ready to be expelled; while in the mean time the air having a tendency to restrain and keep them in, directs them to the sulphur, and keeps them still collected in their place or pabulum, while the combustible matter is diffused all around. *Flame* is, by many, thought to be nothing but a thick sulphur, agitated as before, by elementary Fire; so that the Fire is driven with a great motion about the revolving particles of the sulphur.

As to the nature of Fire, it has, for a considerable time, been disputed, whether it arises from a violent motion of the parts of any body; or whether it be a fluid of a certain kind, different from all others: as it does not appear that the dispute is yet brought to a satisfactory decision, and as it might not be attended with much advantage to give you the arguments in favour of one opinion, without adducing those in favour of the other (which the limits I am obliged to prescribe myself, prevent me from doing) I shall detail none of the arguments on this part of he subject.

When we consider that the elementary Fire is lmost every where present and to be met with: amely, in almost all plants, especially such as con-ist of wood, and compose whole forests; in the ones of animals; in their flesh, and in their blood, s is evident, because when dried they will burn; in o many minerals; in fenny grounds; in coals, rimstone, and saltpetre; nay, even in stone; also n the bowels of the earth to a copious degree: vhen we consider this, I say, and remember the nischievous and powerful effects which it has often roduced; we could not (though it is so useful to s) reflect upon it without horrour, if we were not ssured that there is an over-ruling Power, which olds it safely, and restrains it from evil.

LESSON XXIX.

ON WATER.

Ye, whose vital moisture yields
Life's purple stream, and fresh supply,
Sweet waters, wand'ring thro' the flow'ry fields,
Or dropping from the sky;
Confess the power whose all-sufficient name,
Nor needs your aid to build, nor to support our frame.

WATTS.

If any such person as an Atheist should peruse these Lessons, if he be not yet convinced of the existence of a Deity, let him pass on with me to the contemplation of *Water:* and here I may venture to say, that he will at least agree with me when I assert, that if there had been no such thing as Water in the world, all mankind, and almost all living creatures, even in the midst of a superfluity of air and other food, would certainly perish in a very short time; since thirst, if it be not extinguished, is quickly fatal: all men, and the greater part of the animal kingdom, being unable to exist without drink.

But it may be also observed, that even if it were possible that men, and other creatures, could exist without drinking, their condition would still be very miserable without Water: for without its nourishment, neither grass, nor plants, nor trees, would be able to spring out of the earth; the consequence of which would be, that animals, and consequently mankind, would be deprived of food, as well as drink, whence death must speedily follow. From these passages I would not wish to have it inferred, that it is not in the power of the ALMIGHTY to furnish us with a substitute for Water; this the reader may easily judge is not my intention: my only design is, to ask, if these things be produced by chance as Atheists assert, how it comes about that this same chance is always on our side? For, it appears very odd to me, that it is owing to mere chance, that creatures in general, have the faculty of supporting their lives by Water, and likewise that Water has, by a very *lucky hit*, acquired the properties which are necessary for that purpose!

From the Mosaic account of the creation of the world, we learn, that the division and partition of the Water into proper channels and courses, was part of the workmanship of the second and third days; we there also learn, that the business of the creation was compleated in six days. GOD could certainly have *spoken* the whole world into existence in an instant; but his love for his creatures led him to consult their happiness, to make their felicity flow from their duty: for the regular manner in which HE was pleased to create all things, points out to us a lesson which should never be forgotten: namely, that we should so regulate the manner of spending our time in this world, that the performance of one duty, may not interfere with, or obstruct another.

Water is defined by most physiologists, a clear, insipid, colourless fluid, coagulable into a transparent solid substance called ice, when placed in a temperature of 32° of Fahrenheit's thermometer, or lower; but fluid and volatile in every degree of heat above that; when pure, or freed from heterogeneous particles it is reckoned, by the Peripatetics, one of the four elements.

Water is a very volatile body; being entirely reduced into vapours and dissipated, when exposed to the fire, and unconfined. When heated in an open vessel, water acquires no more than a certain determinate degree of heat, whatever be the intensity of the fire to which it is exposed; which greatest degree of heat, is when it boils violently. It has been found that the degree of heat necessary to make Water boil in an open vessel, is variable, according to the purity of the Water and the weight of the atmosphere. The requisite degree of heat i generally between 205° and 214° of Fahrenheit's thermometer. When the pressure of the air is removed, Water will boil with 90° of heat. Wat when confined in the strong metallic vessel, call *Papin's digester*, may be heated so intensely as t dissolve most earths and to fuse metallic bodies.

Ne

Next to Fire, Water is found to be the most penetrative of all bodies, and the most difficult to be confined. It will pass through leather, bladders, and other substances which will confine air: it will make its way gradually through wood; and is only retainable in glass and some metals. Nay, it was found by experiment, at Florence, that when shut up in a spherical vessel of gold, which was pressed with a great force, it made its way through the pores of the gold.

Water by this penetrative quality alone, may be nferred to enter the composition of all bodies, ve- etable, animal, fossil, and even mineral; with this articular circumstance, that it is easily, and with a entle heat, separable again from bodies it had nited with.—And yet, the same Water, as little ohesive as it is, and as easily separated from most odies, will cohere firmly with some others, and bind em together in the most solid masses; as in the mpering of earth or ashes, clay or powdered bones, ith Water, and then dried and burnt, when the asses become hard as stones; though, without the ater they would have become mere dust or wder. Indeed, it appears wonderful, that Water, ich is an almost universal dissolvent, should ne- theless be, in many instances, a great coagulator.

It has been imagined by some that Water is incom- ssible, and therefore non-elastic: but Mr. *Canton* proved by accurate experiments, that Water ctually compressed even by the weight of the atmosphere. Besides, the diminution of size which Water suffers when it passes to a less degree of heat, sufficiently shews that the particles of this fluid are, like those of all other known substances, capable of approaching nearer together.

But the most remarkable property of Water, is that, which has been already spoken of in the twentieth Lesson; the discovery of which, as it appears to be one of the most curious and important which modern times can boast of, I must again recur to. For this discovery we are indebted to *Count Rumford*, and it is given in his Essays. After proving in a very satisfactory way, that the particles of fluids are incapable of imparting heat *to each other*, and that when their temperature is undergoing any change, an intestine motion is kept up in them, by a successive alteration taking place in the specific gravity of their particles, he proceeds to shew, that "all bodies are condensed by cold without limitation, *Water only excepted*," and describes the wonderful effects produced in consequence of this particular law.

"Though in temperatures above blood-heat (says the Count), the expansion of Water with heat is very considerable, yet in the neighbourhood of the freezing point it is almost nothing. And what is still more remarkable, as it is an exception to one of the most general laws of nature with which we are acquainted, when in cooling it comes within eight or nine degrees of Fahre

" heit's scale of the freezing point, instead of going " on to be farther condensed as it loses more of its " heat, it *actually expands*, as it grows colder, " and continues to expand more and more as it is " more cooled."

After enlarging upon this subject, he proceeds thus:—" As nourishment and life are conveyed to " all living creatures through the medium of " Water; *liquid*, *living* Water; to preserve life, it " was absolutely necessary to preserve a great quantity " of Water in a fluid state, in winter as well as " in summer. But in cold climates the temperature " of the atmosphere, during many months in the " year, is so much below the freezing point, " that, had not measures been taken to prevent so " fatal an accident, all the Water must inevitably " have been changed to ice, which would infallibly " have caused the destruction of every living thing."

Count Rumford then shews how very powerfully this wonderful contrivance tends to retard the cooling of Water, when it is exposed in a cold atmosphere, and its consequent tendency to prevent all those dreadful evils which must have necessarily ensued, had it not been for this remarkable property: but instead of making farther extracts, which, as they must be short, would be inadequate to the purpose, I must refer my young reader to the Essays themselves, for the time bestowed on the perusal of which he will find himself amply repaid.

Water as a fluid, is governed by several laws peculiar to itself, to notice all of which would require a volume: one of its most wonderful properties is, that its *pressure* or *force*, varies in proportion as its depth does, without any regard to its breadth; if it were not for this astonishing property, it would be impossible for ships or any other vessels to put out to sea,—for if the lateral pressure varied with the breadth, it is evident that every sailing vessel would be forced against the nearest shore with great violence, and, of course, there would be an insuperable bar in the way of navigation.

As it would be absolutely impossible to make a calculation of the quantity of subterraneous Water, I shall not attempt it; but as it is a much easier matter to have an idea of the enormous quantity of Water on the earth's surface contained in seas, we will here set about it: it is a reasonable supposition, that of the earth's surface two-thirds are seas; now if we suppose one common depth to be the tenth part of a mile, we shall find that there is Water sufficient to cover the whole globe to the height of six hundred feet; and if this Water were reduced into one mass, it would form a globe of more than sixty miles diameter.

In reflecting upon the various changes of Water, we have a curious kind of *perpetual motion* placed in view:—Vapours are raised from the ocean, by means of the sun and other agents in the process of evaporation; and these are transported by the winds, &

&c. through every climate: the progress of these vapours is interrupted by the tops of mountains, and other causes, whence they accumulate into clouds, and descend in the form of rain, snow, &c. as explained in the nineteenth Lesson: after having refreshed the surface of the earth, the surplus proceeds, by virtue of its intrinsic gravity, to steer its course through rivulets, &c. to the lower parts, where it meets with rivers, which conduct it to the sea; from whence it again undergoes a similar process, and so on continually. Here I cannot help adverting to the great utility and advantage of the distribution of the Waters and the dry land; which although it may seem rude and undesigned to a careless view, yet it is admirably adapted to our benefit and convenience. The Earth and the Waters are so placed about the globe, as to minister to one another's uses. The great oceans, with the seas and the lakes, are so extensive, and so situated as to produce sufficient vapours for clouds and rains, to mitigate the heats and to refresh the earth with fertile showers. The mountains and the less hills are distributed in such a manner as to afford proper situations for fountains, and the sources of rivers; and this, whether they are supplied from the condensation of vapours, or from subterraneous channels. Nay, so abundant is this great blessing which the most indulgent Creator hath bestowed upon us, by means of the distribution of the Earth and Waters, that there is more than a scanty, bare sufficiency, even a surplus, and plenty of this most necessary article afforded to the world: this too, is so well ordered, by means of the hills and vales on the surface of the earth, as not to suffer any sufficient quantity to remain stagnant at one time, to be of any material injury to mankind. How ought our hearts to overflow with gratitude, joy, and praise, for such beneficence, mercy, and wisdom, as are here made manifest!

LESSON XXX.

FOUNTAINS or SPRINGS.

Tell by what paths, what subterranean ways,
Back to the fountain's head the sea conveys
The refluent rivers, and the land repays.
Tell what superiour, what controlling cause,
Makes waters in contempt of nature's laws,
Climb up, and gain th' aspiring mountain's height,
Swift and forgetful of their native weight.

BLACKMORE.

THE conjectures of philosophers concerning the rigin of Fountains, have been various; and though he subject has been discussed frequently for more han two thousand years, it is to be lamented that is yet attended with considerable difficulty.

Aristotle, whose thoughts on this matter have ached us, was of opinion, that the air contained in e caverns of the earth, being condensed by cold ar its surface, was thereby changed into water, d making its way through, formed fountains or rings. Most of the ancient philosophers after m, embraced this opinion; but the moderns have tirely rejected it, as they have no experience of y such transmutation of air into water.

Among the hypotheses which have lately been made use of to account for the formation of Springs, I shall describe to you only three, they being the only ones which in my opinion carry with them any appearance of probability.

The first hypothesis is, that Springs are owing to rain and melted snow. The water penetrates the earth till it meets with a soil, or stratum of earth, of a nature sufficiently solid to sustain it, and prevent it from descending lower in such minute quantities. It then glides gently along in that way which the stratum declines, and in its passage meets with fresh quantities which have been filtered through in the same manner; these gradually descend together till they arrive at an aperture in the surface, through which they escape and form a spring, and perhaps the source of a brook or rivulet.

Another hypothesis, so nearly allied to that just mentioned, that it is almost unnecessary to distinguish them in a work of this kind, is, that of the ingenious Dr. Halley. When this gentleman made his celestial observations upon the tops of the mountains at *St. Helena*, he found that the quantity of vapour which fell there (even when the sky was clear), was so great, that his observations were thereby much impeded: his glasses were so covered with water through the condensation of the vapours, that he was obliged to wipe them every ten minutes. In reflecting upon this, he was led to suppose that the water raised by evaporation from the seas and la-

rge rivers might afford a sufficient supply for the
ater discharged by Fountains. In order to deter-
ine, with some degree of accuracy, how much
ater would be raised in vapour in any space of
ne, he took a vessel of water salted to the same
gree with that of sea-water, in which he placed a
ermometer, and by means of a pan of coals brought
e water to the same degree of heat as would be
oduced by the sun in summer: he then affixed the
sel of water with the thermometer in it, to one
d of a pair of scales, and exactly counterpoised it
h weights on the other. Then, at the end of
o hours, he found by the alteration in the weight
he vessel, that a sixtieth part of an inch in the
th, of the water was gone off in vapour; and
efore, in twelve hours, one tenth of an inch
uld have gone off.

rom this experiment the Doctor calculates (in as
urate a manner as the subject will admit of), the
ntity of water raised by evaporation from the
diterranean Sea, to be at least five thousand two
dred and eighty millions of tuns of water in a
; and from the *river Thames* twenty millions,
e hundred thousand tuns per day. If, as it ap-
ed reasonable to conclude, other seas and rivers
ld afford vapour in the same proportion when
are acted upon by the sun in a similar degree;
greater or less proportions as they are acted
in a greater or less degree, this was thought,

by the Doctor, a source abundantly sufficient for the supply of Fountains.

The waters thus raised by evaporation, he imagined would keep rising, and float in extremely small and light bubbles, till being condensed by the cold, they become specifically heavier than the air when they would descend, or being driven by the winds against the sides of mountains (some of which surpass the usual height to which the vapours would of themselves ascend) are compelled by the stream of air to mount up with it to the tops of them, and being presently precipitated, enter the crannies of the mountains, and glide down as described in the former hypothesis.

In the third hypothesis it is imagined, that the water is conveyed from the sea to the places where there are Fountains by some subterranean passage; either by ascending in very small portions in capillary tubes, or by being conveyed in larger portions by means of *Charybdes*. Charybdis is a name given to an opening which is supposed to be in the bottom of the sea. The *Fluxus moschonicus* or *Maalstrome*, on the coast of Norway, is supposed to be owing to some such subterranean indraught; and it is asserted also, by several, that the Mediterranean sea could not be emptied of the vast quantities of water which it receives, but would overflow its boundaries, unless part were taken off by some such charybdis, which is either in some part of the bason of that sea, or near the mouth of it.

In support of this supposition may be mentioned that strong under-current, described by all those who have treated of this sea. A large charybdis, placed near the streight's mouth, may be hid under the immensity of waters there, and as it would continually draw in the lower waters in large quantities, it would necessarily cause such an under-current.

If it be admitted, that there are such orifices at the bottoms of some seas, as we suppose these charybdes to be, it is natural to enquire of what use they are. And perhaps none will offer a more probable answer to this enquiry, than those who say, the waters of the sea are by such means conveyed by subterranean channels to the sides of mountains and hills, whence they gush out at some apertures and form springs.

Each of the hypotheses here advanced admits of objections: to the first two it is objected, that they are not the only ways in which Springs are produced: for as causes may always be measured by heir effects, it is unphilosophical to conclude, that n inconstant cause will produce a constant effect—and therefore Springs which constantly send forth he same, or nearly the same quantities of water, annot be supplied in the manner pointed out under he two first hypotheses, where the causes, as rain, now, or vapours, are inconstant or variable.

Suppose the truth of this remark be allowed, it oes not follow from this, that all Springs are prouced in some other way. Perhaps, if the nature of Springs, and the nature of the hypotheses be compared, we shall, by such comparison, be brough to a very different conclusion.

Let us consider the first hypothesis. Neither rai nor snow continues without intermission; but there are intervals between the showers, during which neither rain nor snow descends. Is it not probable, that those Springs which flow and stop alternately, and are therefore called, *intermitting* Springs, are caused by these showers? It may, perhaps, be objected, that in such Springs, the time of flowin does not seem at all connected with the time of the shower. But in answer to this, I would observe, that it is not an easy matter to judge of this, as i cannot be determined which was the shower tha caused the flowing of the Spring. Those shower which cause the Spring to flow, may perhaps fall a a great distance from it; while those which fall nea it may have an effect upon some Spring at a distance. Or there may be four or five showers fal in the interval, between the flowing of the Sprin and that shower which caused it to flow.

But perhaps it may be said, that this hypothes will not satisfactorily account for those Spring which ebb and flow every six hours, or some suc short period: it will not; we must therefore hav recourse to the third hypothesis, and suppose th Springs which ebb and flow thus regularly are supplied by *charybdes*, placed in some parts of the s of such a depth as to cause their discharges to b

effecte

ected by the tide, and where the tide ebbs and
ws at periods similar to those of the Spring.

The second hypothesis will assist us in account-
g for *reciprocating* Springs, or those which flow
nstantly with a stream subject to increase and de-
ease. If these are supplied by condensed vapours,
eir streams will increase or decrease, in proportion
the vapour which supplied them was produced in
reater or less degree by the union of heat, wind,
l other causes.

As to those Springs which are constant and regular
their discharge, we may suppose, that they are
plied from *charybdes*, situated at such a depth as
be not at all affected by the ebbing and flowing
he sea; but convey the water always in equal
tions in equal times, and, of course, supply the
ings with regularity.

Against this hypothesis of charybdes, I imagine
o objections will be erected, but I think neither of
m will overset it. And first, it may be said, that
any of the Springs are supplied in this way, the
rybdes must be numerous, and therefore it is
prising that not more of them are discovered.
e I would reply, that if there are many, suppose
harybdis to a Spring, it follows that they must,
paratively speaking, be very small, and of course
r effects may not be perceptible upon so large
deep a body of water. A hole a quarter of an
n in diameter would let out much liquor from a

full hogshead, but it would not disturb the tranquillity of the liquor at the surface.

But in the second place it may be said, that I cannot explain the way in which water is conducted high above its source: I cannot; but this is no pro that it is not so conducted—no more than it woul be a proof that a man was lifeless, because he coul not account for his own existence. The properti of various kinds of matter have been determined but only in such circumstances as would admit experiments being tried: in those cases where w can only form a judgment by analogy, we a always liable to fall into errour, though we m sometimes escape it.

Since the late discoveries in Electricity and Ma netism, matter has been found to possess qualiti which philosophers of an earlier period were n aware of: and in all probability, matter different modified, or under different circumstances, m possess properties which are yet undiscovered. L this spur us on to fresh exertions in the cause Philosophy; and if, after all, we are obliged confess ourselves purblind and ignorant in a g degree, let us not despair; for Religion points to us a cheering prospect: she directs us to a peri when all our faculties shall be expanded, and all enquiries satisfied:

"When God's almighty hand shall lift the curtain hig
"And all creation's wonders open to our eye."

LESSO

LESSON XXXI.

ON THE TIDES.

——Now the mighty mass of water swells
Resistless, heaving on the broken rocks,
And the full river turning, till again
The tide revertive, unattracted leaves
A yellow waste of idle sands behind. THOMSON.

PHILOSOPHERS in every age of the world have een greatly puzzled to explain and account for the *ides* of the sea, which ebb and flow twice in venty-four hours; but in despite of every attempt, e doctrine of them remained in obscurity, until e great Sir Isaac Newton developed the mystery. his astonishing man having demonstrated that there a principle in all bodies, by which they mutually aw or attract each other, in certain proportions cording as their distances or size vary; as fluids e very easily put in motion by any force acting pon them, it follows, that those parts of the sea hich are immediately below the moon, must be awn towards it, and consequently wherever the oon is nearly vertical, the sea will be raised, hich occasions the flowing of the Tide there. A similar reason occasions the flowing of the Tide likewise in those places where the moon is in the nadir, and which must be diametrically opposite to the former: for in the hemisphere farthest from the moon, the parts in the nadir being less attracted by her than the other parts which are nearer to her, gravitate less towards the earth's centre, and consequently must be higher than the rest. Those parts of the earth, on the contrary, where the moon appears on the horizon, will have low water: for as the waters in the zenith and nadir rise at the same time, the waters in their neighbourhood will press towards those places to maintain the equilibrium; to supply the place of these, others will move the same way, and so on, to the places ninety degrees distant from the zenith and nadir, where the water will be the lowest.

Let the diurnal rotation of the earth be now taken into the consideration, and it is evident, that every part of it will pass twice through the elevated, and twice through the depressed parts, so as to produce two Tides in the day. But the places of high and low water are now altered; for, the motions impressed of rising and falling are retained for some time after the forces which produce them are greatest: and the greatest elevation happens about three hours after the meridian of the place has passed under the luminary, when it points about half a quadrant to the east of it: and the water continues to descend for 90 degrees hence, or till the meridian points about half a quadrant to the east of the next quarter. But in shallow seas, and in the mouths of rivers, the Tides are retarded till the fourth, fifth, or perhaps, sixth hour, after the meridian of the place has passed under the luminary.

The force of the sun to raise the Tides, is about four and a half times less than that of the moon: but it is evident, that when the forces of both conspire, so as to elevate and depress the water in the ame places, then the Tides are greatest, and are alled *spring Tides*, which happen about the new nd full moon.

When the moon is in her quarters, the water is ost elevated by her, where it is most depressed by he sun, and the contrary; and the tides, being aised by the difference of their forces, are least, or *eap Tides*. But because of the continuation of otion, these effects are greatest and least, some ime after the forces are: so that the greatest spring ides happen three days after the new and full oons; and the least neap Tides three days after the rst and third quarters.

By the action of the sun the time of high water also changed, being sometimes sooner, and some-imes later than it would happen by the action of e moon alone. For in the transit of the moon om new or full to a quarter, when the tide raised y the the sun alone would precede that raised by e moon alone, the high water which is produced y their united actions, will happen at an intermediate time, nearer to, but yet before, the time at which it would be raised by the action of the moon. But when the moon is passing from her quarters to the new or full moon, since the sun alone would produce a greater Tide, the time of high water is retarded.

The greatest spring Tide will happen when the moon is in perige; if other things are the same: and the succeeding spring Tide, when the moon is in apoge, will be least. But, because the earth is nearer the sun in winter than in summer; and the effect of a luminary is also greater, the nearer it approaches to the plane of the equator; the greatest spring Tides, and the least neap Tides will generally happen immediately after the autumnal, and before the vernal equinox.

In places remote from the equator, the two immediately succeeding Tides are unequal, whenever the luminary declines from the equator. Thus it is observed, that the evening tides in summer exceed the morning Tides; and the contrary, in winter. For, if the greatest elevation immediately under the luminary points to one side of the equator, the opposite greatest elevation points as much to the other side. And those places, which are on the same side of the equator with the luminary, approach nearer to the greatest elevation, when the luminary is above the horizon, than to the greatest opposite elevation, when the luminary is below the horizon.

This inequality is greatest, when the sun and moon have the greatest declination. It is also greatest in places most remote from the equator. The nearer the place approaches to the poles, the farther it is removed from the greatest elevation on the opposite side of the equator. Thus the less Tide is continually diminished, till at last it entirely vanishes, and leaves only one Tide in the day. Hence it is found by observation, that, when the moon has declination, there is only one Tide in twenty-four hours in all places in the polar regions, in which the moon is either always above, or always below the horizon, during a whole rotation of the earth about its axis.

These things would happen uniformly in the manner above described, if the whole surface of the earth were covered with water; but since there is a multitude of islands, continents, &c. which interrupt the natural course of the water, varieties of appearances are to be met with in different places, which cannot be explained without regarding the situation of shores, streights, and other objects: and as this would lead me too great a length, without being of any utility, I shall here take my leave of the subject.

LESSON XXXII.

ON DAYS AND NIGHTS.

My God, all nature owns thy sway,
Thou giv'st the Night, and thou the Day!
When all thy lov'd creation wakes,
When morning, rich in lustre, breaks,
And bathes in dew the opening flow'r,
To thee we owe her fragrant hour;
And when she pours her choral song,
Her melodies to thee belong!
Or when, in paler tints array'd,
The Evening slowly spreads her shade;
That soothing shade, that grateful gloom,
Can more than Day's enliv'ning bloom,
Still ev'ry fond and vain desire,
And calmer, purer thoughts inspire;
From earth the pensive spirit free,
And lead the soften'd heart to thee!

MISS WILLIAMS.

PREVIOUS to the dawn of the true philosophy, when several erroneous opinions were entertained by philosophers, the principal one with regard to the form of the earth, was, that it was a vastly wide extended plain, that the visible horizon bounded the earth, and the ocean bounded the horizon: to account

count for Day and Night it was then imagined that the sun in the morning emerged from the eastern ocean, and, after pursuing his daily track, was immerged into the western ocean, whence in the course of the Night he travelled on to the eastern, in order to perform his next diurnal journey; which is such an absurd doctrine, as is now entirely laid aside; except indeed, by the most illiterate.

But as my young readers will readily admit the near approach of the earth to a spherical form, I must endeavour to explain to them the occasion of *Day and Night*, in a more rational manner.—On account of the immense distance of the earth from the sun, and the earth's minute size when compared with him, it is evident that the rays of light emitted from that luminary (setting aside the effects of the atmosphere) will fall upon the earth in parallel directions, and will always illuminate a hemisphere of the earth, whilst the other hemisphere remains in darkness. Hence then, so long as any particular place on the earth continues in the darkened hemisphere, it will be night at that place: but, as soon as that place, by the diurnal rotation of the earth from west to east, is brought to the verge of the enlightened hemisphere, then is *Day-break*; and

——The *morn*, in russet mantle clad,
Walks o'er the dew of yon high eastern hill.

SHAKSPEARE.

When the meridian of that place, is by gentle degrees brought directly beneath the sun, it is then *Noon* at that place, and at every place in the enlightened part of the same meridian: but in the darkened part of the same meridian it is then midnight. As the place is carried forward, the afternoon hours keep wasting, until it arrive at the edge of the darkened hemisphere, and then approaches sober *Evening*, shedding her dusky influence round: that part of the globe which is directly opposite, is, at the same moment just emerging from darkness into Day-light: and thus, by the earth's rotation, the whole is obviously accounted for.

——When to the western main the sun descends,
To other lands a rising day he lends;
The spreading dawn another region spies,
And o'er the antipodes * begins to rise:
While we in sleep's embraces waste the night,
The climes oppos'd enjoy meridian light;
And when those lands the busy sun forsakes,
With us again the rosy Morning wakes. GAY.

To explain the reason of the *different lengths* of Days and Nights will be part of the subject of the next Lesson: but I shall first present you with an agreeable method of shewing all those places of the earth which are enlightened by the sun at any time. In order to this, let a terrestrial globe be taken from its several appendages, and placed upon a pedestal in the sun-shine, in such a manner that its north pole may point directly towards the north pole of the heavens, and that the meridian of the place where you are may be directly toward the south. Then the sun will shine upon all the like places of the globe, as he does really on the earth, rising to some when he is setting to others; as you may perceive by noticing where the enlightened half of the globe, is divided from the half in the shade: all those places, on which the sun shines at any time, having day; and all those on which he does not shine, having night: also, when any place is near the middle of the enlightened part, it is then nearly noon there; and those places which are about the middle of the darkened part, have then midnight.

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* Those people are called *Antipodes*, who, living on the other side of the earth, have their feet directly opposite to ours.

The vicissitudes of Days and Nights have raised in the minds of several prose and poetical writers very serious and excellent reflections concerning the sublunary state: with one of which this Lesson may be concluded.

For ever running an enchanted round
Passes the Day, deceitful, vain, and void,
As fleets the vision o'er the formful brain,
This moment hurrying wild th' impassion'd soul,
The next in nothing lost. 'Tis so to him
The dreamer of this earth, an idle blank;
A sight of horrour to the cruel wretch,
Who all day long in sordid pleasure roll'd,
Himself an useless load, has squander'd vile,

Upon his scoundrel train, what might have cheer'd
A drooping family of modest worth:
But to the generous still improving mind,
That gives the hopeless heart to sing for joy,
Diffusing kind beneficence around,
Boastless, as now descends the silent dew,
To him the long review of order'd life
Is inward rapture, only to be felt. THOMSON.

LESSON XXXIII.

ON THE SEASONS.

Observe the circling year: how unperceiv'd
Her seasons change! behold, by slow degrees,
Stern winter tam'd into a ruder spring;
The ripen'd spring a milder Summer glows;
Departing summer sheds Pomona's store;
And aged autumn brews the Winter's storm.

ARMSTRONG.

I THINK there is scarcely one of the youthful perusers of these pages, but must have an inclination (if he be not already acquainted with it) to be made sensible in some measure of the reason and cause of that agreeable succession of the *Seasons* which constitute the year. Here we meet with a variety, the limits of which are not ascertainable. With pleasure we behold the varied appearances of nature: whether Spring arrays herself in her spotted robe; or Summer scorches with his sultry beams; or Autumn pours forth her exuberant stores; or Winter with his howling tempests drives us to our habitations—still we are admirers of nature, and disposed,

———————" To mark the mighty hand
" That, ever busy, wheels the silent spheres;
" Works in the secret deep; shoots streaming thence
" The fair profusion that o'erspreads the Spring;
" Flings from the sun direct the flaming day;
" Feeds ev'ry creature; hurls the tempest forth;
" And as on earth this grateful change revolves,
" With transport touches all the springs of life."

It may have been observed that, when explaining the nature of the tides, I said, "The earth is nearer the sun in Winter than in Summer:" this may to many persons appear improbable, but it is absolutely fact: for the apparent diameter of the sun is about 32° 48′ on the shortest day, and only 31° 30′ on the longest: whence it is manifest that the distance of him from us must be less in the former case than in the latter. But the effects occasioned by the difference of distance are more than counterbalanced to us inhabitants of the earth's northern hemisphere: for though the sun in Summer be farther from us; yet, on account of his being more nearly in a vertical position, his rays fall more directly on any part, and of course are denser and thicker; and this, not only because the same quantity of rays fall on a less space of the earth, but because they are not so much refracted and weakened by the atmosphere, as when they fall more obliquely thereon.

The diversity of seasons is occasioned by the earth's annual motion in her orbit; and in this motion

tion two peculiar circumstances must be well understood, because on their combination the whole phænomena depend. 1. The earth's axis does not always keep the same relative situation with regard to the sun as the centre of its orbit; but, on the contrary, it always keeps very nearly in a parallel position, or points always towards the same part of the heavens. 2. The axis of the earth is inclined to the plane of the earth's orbit, which may be conceived by supposing a spindle put through a ball, with one end of it touching the ground, or a table; then by moving the ball directly forwards whilst the one end of the spindle continues to touch the ground, or table, and the other points toward the heavens, a tolerable conception of the inclination of the earth's axis to her orbit may be obtained.

The most easy method of acquiring a right idea of the varieties of the Seasons, and the different lengths of days and nights, will be by an experiment which I shall now endeavour to describe. Let two large circular hoops nearly of equal sizes be procured: let one of these be fixed in an horizontal position, and let the other be fixed within it in such a manner as to cross it in an angle of 23½ degrees, having one half above the horizontal hoop, and the other half below. When night is arrived the flame of a candle must be fixed exactly in the centre of the hoops, and a small terrestrial globe must be taken from its appendages, having a string tied to its north pole, from which string the globe may be suspended. In this experiment, the candle flame must be supposed to represent the sun, and the inclined hoop the earth's orbit: just on the inside of this hoop, the globe suspended from the string must be carried gently round in a direction from west to east; then its axis will always be parallel to itself, and the various seasons will be represented in the different parts of the path. Thus, when the globe is at one of the places where the hoops intersect, its poles are equally illuminated, and the days are every where of the same length: then Spring commences to the inhabitants of the northern hemisphere; being on the 20th of March. As the globe is carried on, the days keep increasing, until it has arrived at the lowest part of the hoop; when the north pole will appear a considerable way in the illuminated hemisphere, and the south pole as much in the darkened one: then is our beginning of Summer and their beginning of Winter; and here it may be perceived that any parallel of latitude toward the north pole is considerably more in the enlightened hemisphere than in the darkened one; while, on the contrary, in the southern hemisphere, a far greater part of the parallel of latitude is darkened than enlightened: hence, our days are then longest, and theirs shortest; which happens on the 21st of June. The globe being carried on until it arrive at the intersection of the hoops on the other side; each of its poles is again illuminated, and the days every where of equal length, because each parallel of latitude is half in the enlightened and half in the darkened part: Then commences Autumn with us, being on the 22d of September. As the globe is carried on, the days with us shorten, until it has arrived at the highest part of the hoop: then the north pole is in the darkened hemisphere, and the southern one, in the enlightened part; our day is at the shortest, while in the southern hemisphere the day is longest: Our Winter commences and their Summer; being on the 21st of December. As the motion of the globe is continued, our days lengthen; and when it has again arrived at the intersection of the hoops, we have Spring, and the inhabitants of the southern hemisphere have Autumn. In the course of this experiment it will be found, that each of the poles continues enlightened half through the annual revolution, and darkened through the other half: consequently, at the poles of the earth, there is but one day and one night through the year.

At the equator the rays of the sun fall perpendicularly on the earth, and therefore act with more power; whence arises the great heat of the torrid zone. On advancing towards both poles, the rays fall more and more obliquely, and therefore act with less force and less; whence this space is occupied, first by the temperate zones extending on each side the tropics, and then by the frigid zones extending from these to the poles. So weak is the power of the sun in these last, owing to the great obliquity with which its rays strike the earth, that they are buried in almost perpetual snow and ice. But these are merely the differences of *climate:* the differences of *Season* depend not upon these causes merely, but also upon the length of time that any portion of the earth is exposed to the solar rays. During the short days the influence of the sun is less, both with respect to the intensity of its rays, and the time of their continuance, which therefore produces Winter: during the long days it is greater in both respects, and therefore causes Summer; the middle Seasons of Spring and Autumn correspond with the equality of nights and days. It is to be remarked, however, that this correspondence is not perfectly exact; for the severest frosts usually take place after the days have begun to lengthen, and the most oppressive heats are found to happen when the days are decreasing: the reason of which is, that the earth having imbibed more heat than it gave out during the Summer months, is not exhausted of its superabundant warmth till about the close of the year: in like manner, on account of the waste of the earth's heat being greater in Winter than its supply, it continues to imbibe heat during the Spring, and is not saturated till after the Summer solstice. Hence also arises the difference between the Spring and Autumn, though the position of the sun in respect to the earth, is in both the same. The heat of the Spring is inferiour to that of Autumn, both in point of regularity and degree;

for, on account of the deficiency of warmth in the earth, it is constantly imbibing the heat from the lower part of the atmosphere; hence originates a large collection of clouds, which intercepting the rays of the sun, combines together with the absorption of the earth, to deprive the air of much of its heat. Whereas in Autumn, the earth being hotter than the air, gives out regularly a large portion of warmth, which naturally tending to disperse the clouds, affords a free passage to the solar rays: thus Autumn ought in general to be hotter than spring, for these two reasons; first, that the earth itself gives out a considerable quantity of heat; and secondly, that the rays of the sun meet with fewer interruptions in passing thence to the earth. At the equator there is no proper difference of Seasons, except as occasioned by rainy or windy periods, which proceed from other causes; and the case is much the same on each side of it for some distance.

Several of the British poets have presented us with a variety of descriptions of the Seasons; some serious, some humourous and comic; as an instance of the latter, we have a droll account of Winter's effects, in a song in *Shakespeare*'s play of "*Love's* "*labour lost:*" but the obvious similarity between infancy, youth, manhood, and old age, of human life; and Spring, Summer, Autumn, and Winter of the year, suggests a subject for the most sublime reflections; the excellence of those which Mr. *Thomson* has made on this head, will supersede the necessity of my apologizing for giving them insertion here.

———Behold, fond man!
See here thy pictur'd life; pass some few years,
Thy flowering Spring, thy Summer's ardent strength,
Thy sober Autumn fading into age,
And pale concluding Winter comes at last
And shuts the scene. Ah! whither now are fled
Those dreams of greatness? Those unsolid hopes
Of happiness? Those longings after fame?
Those restless cares? Those busy bustling days?
Those gay-spent festive nights? Those veering thoughts,
Lost between good and ill, that shar'd thy life?
All now are vanished! virtue sole survives,
Immortal never failing friend of man,
His guide to happiness on high. And see!
'Tis come, the glorious morn. The second birth
Of heav'n and earth! Awakening nature hears
The new creating word, and starts to life,
In every heighten'd form, from pain and death
For ever free. The great eternal scheme,
Involving all, and in a perfect whole
Uniting, as the prospect wider spreads,
To reason's eye refin'd clears up apace.
Ye vainly wise! ye blind presumptuous! now,
Confounded in the dust, adore that Power
And Wisdom oft arraign'd; see now the cause
Why unassuming worth in secret liv'd,
And died neglected; why the good man's share
In life, was gall and bitterness of soul;
Why the lone widow and her orphans pin'd
In starving solitude; while luxury,
In palaces, lay straining her low thought,
To form unreal wants; why heav'n-born truth,

And moderation fair, wore the red marks
Of superstition's scourge; why licens'd pain,
That cruel spoiler, that embosom'd foe,
Imbitter'd all our bliss. Ye good distrest!
Ye noble few! who here unbending stand
Beneath life's pressure, yet bear up a while,
And what your bounded view, which only saw
A little part, deem'd evil, is no more:
The storms of Wintry time will quickly pass,
And one *unbounded spring* encircle all!

THOMSON'S WINTER.

LESSON XXXIV.

VEGETABLES OR PLANTS.

Your contemplations farther yet pursue;
The wond'rous world of Vegetables view:
Observe the forest oak, the mountain pine,
The tow'ring cedar, and the humble vine,
The bending willow that o'ershades the flood,
And each spontaneous offspring of the wood.

BLACKMORE.

MY young readers having undoubtedly been often delighted, in viewing the beauties of the Vegetable Creation, I am in hopes of contributing to their satisfaction, while I endeavour to explain to them the nature of *Vegetables* and *Vegetation*.

A Vegetable or Plant is an organized body, consisting of various parts, taking in its nourishment usually by a root, and increasing its dimensions by growth. Vegetables may be divided into three classes, namely, herbs, shrubs, and trees. Herbs are those sorts of Vegetables whose stalks are soft, and have no wood in them; as parsley, lettuce, violets, grass, thistles, and an infinite number of others. Shrubs are those Plants which, though woody, never grow into trees, but bow down their ranches near the earth's surface: such are those lants which produce roses, honeysuckles, gooseberries, raspberries, and the like. But trees shoot up n one great stem or body, and rise to a considerable istance from the ground before they spread their ranches: as the oak, the ash, the elm, the beech, he fir, the walnut tree, the pear tree, and many thers.

The most considerable parts of Plants are the oot, the stalk or stem, the leaves, the flowers, and he seed: most Plants have these several parts; hough there are some that have not all of them: he aloe, for instance, has no stalk; the savine, has o leaves; the fern, has no flowers.

The uses of most of the parts of Plants, are very bvious; thus, the root evidently serves as a balance r counterpoise to the head, and by that mean enbles the Plant to stand firmly in the ground. In hat other way could enormous oaks be kept upight and fixed, but by the counterbalance of their xtensive, turgid roots? The fibrous parts of the oots of Plants, like so many mouths, absorb nutrious juices from the earth, and thus convey to the lants the chief of their nourishment. The root lso performs the part of the parent, by preserving e embryo Plants in her bosom, during the severity f the winter, in form of bulbs or buds.

The trunk, or stem of Plants, consists of various rts, as bark, wood, pith, sap vessels, &c. The rk of Plants, performs the same offices to them, that the skin does to animals; it clothes and defends them from injuries, inhales the moisture of the air, and conveys from the Plant the superfluous moist particles. The bark (as well as the wood) is supplied with innumerable vessels, which convey the fluids to and from every part of the Plant; the wood also is furnished with others, which contain air, and are distributed through its substance. The stability of trees and shrubs consists in the wood, which corresponds with the bones of animals. The pith, which is a fine tissue of vessels originating in the centre of the stem, is supposed to be the seat of life. The fluids of Plants are, the sap, analogous to the blood of animals; and the proper juice, which is of various colours and consistence, in different individuals; as white or milky in the dandelion, resinous in the fir, and producing gum in cherry or plum trees.

The leaves contribute both to the benefit and ornament of the Plant: they are supposed to answer the purpose of lungs; and by their readiness to be moved by the wind, they may in some measure act the part of muscles. They are very porous on both their surfaces, and inhale and exhale freely. In some Plants (as Venus's Fly-trap), the leaves are armed with long teeth, like the antenna of insects; they are so irritable, that when an insect creeps upon them, they fold up, and crush or pierce it to death.

The uses of the flowers and seed, are too evident to need enumeration.

The most general method of propagating Plants is by seed: some, however, are raised by a part of the root of the old Plant, set in the ground, as potatoes; others, by new roots propagated from the old ones, as hyacinths, and tulips; others by cutting off branches and putting them into the ground, which will there take root and grow as vines; and others re propagated by grafting, and budding or inoculation.

What is most difficult with respect to Plants (and what has been the subject of much controversy, though yet undetermined), is to explain the manner n which they receive their nourishment The earth as not so much to do in this business as has been commonly supposed. This is known from the experiments of Mr. Boyle and Dr. Woodward: these gentlemen raised several Plants in earth watered with rain or spring water, and even distilled water; nd upon weighing the dry earth, both before and fter the production of the Plants, they found that ery little of it was diminished or taken up by the Plant.

If the earth contributes so little towards the production and nourishment of Plants, it seems natural apprehend that water must be much concerned; nd that this is the case in great measure is evident, from the quantity of water which most plants require to keep them in a state of health and vigour.

But there is some other agent besides water, else, how can the growth of Plants in sandy desarts where it seldom rains be accounted for, and these Plants such as contain juices in great abundance?

Dr. Hunter, so well known and so justly celebrated, both as an anatomist and a naturalist, is induced by a number of experiments accurately conducted, to believe, that all Vegetables receive their principal nourishment from oily particles incorporated with water by means of an alkaline salt, or absorbent earth. Till oil is made miscible, it is unable to enter the radical vessels of Vegetables; and on that account, Providence has bountifully supplied all natural soils with chalky or other absorbent particles: and those soils which are assisted by art are full of materials for that purpose; as lime, marl, and the volatile alkaline salt of putrid dunghills.

The argument in favour of oil being the principal food of Plants is confirmed by the observation, that all Vegetables, whose seeds are of an oily nature, are found to be remarkable impoverishers of the soil; as hemp, rape, and flax: and the best manures for lands worn out by these crops, are such as have a good deal of oil in their composition, provided that they are laid on with lime, chalk, marl, or soap-ashes, so as to render the oily particles miscible with water.

But Plants not only receive nourishment by their roots, but also by their leaves. Vegetables that have a succulent leaf, such as peas, beans, and buck

wheat, draw much of their nourishment from the
air, and on that account impoverish the soil less than
wheat, oats, barley, or rye, the leaves of which are
of a firmer texture. The leaves of all kinds of grain
are succulent for a time, during which period the
Plants take little from the earth; but as soon as the
ear begins to be formed, they lose their softness,
and diminish in their attractive power. The radical
fibres are then more vigorously employed in ex-
racting the oily particles from the earth, for the
ourishment of the plant.

The leaves of Plants serve not only to imbibe the
ew and rain, which contain salt, sulphur, &c. but
hey serve also as excretory ducts to separate and
arry off the redundant watery fluid, which by
eing long detained in the Plants, would turn
ancid and prejudicial to them. The annual sun
ower is an extraordinary instance of this fact; it is
id to perspire nineteen times as much as a man in
venty-four hours. Fine weather encourages the
erspiration of Vegetables; but in heavy, moist, and
et weather the inhalation is greatest. The effluvia
Plants ~~is thought~~ unwholesome to persons of de-
ate constitutions, but particularly so at night, and
a dull state of the atmosphere; the matter per-
ired by the yew tree in particular, is said to be
ry noxious.

Let us now endeavour to illustrate the subject of
getation, by taking a view of what happens to a
an after it has been committed to the earth. In a

few days, sooner or later, according to the temperature of the weather and disposition of the soil, the external coverings open at one end, and disclose to the naked eye part of the body of the grain. This substance consists of two lobes, between which the seminal Plant is securely lodged. Soon after the opening of the membranes, a sharp pointed body appears which is the root. By a kind of instinctive principle (if the expression may be allowed), it seeks a passage downward, and fixes itself into the soil. At this period the root is a smooth and polished body, and has, perhaps, but little power to absorb any thing from the earth, for the nutriment of the germ. The two lobes next begin to separate, and the germ, with its leaves, may be plainly discovered. As the germ increases in size, the lobes are farther separated, and the tender leaves, being closely joined, push themselves forward in the form of a wedge. These leaves take a contrary direction to that of the root: they seek a passage upward; which, having obtained, they lay aside their wedge-like form, and spread themselves in an horizontal direction, as being the best adapted for receiving the rains and dew. The radicle, every hour increasing in size and vigour, pushes itself deeper into the earth, from which it now draws some nutritive particles. At the same time the leaves of the germ, being of a succulent nature, assist the Plant by attracting from the atmosphere such particles as the tender vessels are fit to convey. These particles, however, are of a watery kind, and have not in their own nature a sufficiency of nutriment for the increasing Plant. Vegetables, as well as animals, during their tender state, require a large share of balmy nourishment. As soon as an animal is brought to life, the milk of its mother is supplied in a liberal stream: but, at this period, the tender germ seems only to have the crude and watery juices of the earth for its support: this, however, is not the case; for the Vegetable lives upon a similar fluid, though differently supplied. For its use the farinaceous lobes are melted down into a milky juice, which as long as it lasts is conveyed to the tender Plant, by means of innumerable small vessels which are spread through the substance of the lobes; and which, uniting into one common trunk, enter the body of the germ, and thus supply that balmy liquor, without which the Plant must inevitably have perished, its root being then too small to absorb a sufficiency of food, and its body too weak to assimilate it into nourishment. Thus admirable and well contrived is the method of Providence, in supporting the Plant in its earliest and tenderest stages! As the Plant increases in size, the balmy juice diminishes, till at last it is quite exhausted. The trunk of small vessels then dries up, and the external covering of the seed appears connected with the root in the form of a shrivelled bag. In the process of vegetation there is no mortality; from the moment that the seed is lodged in its parent earth, the vegetative soul begins its operations,

tions, and in the whole successive gradation of them, illustrates the wisdom, power, and bounty of Him, who created and rules the Universe!

These attributes of the ALMIGHTY are also strikingly manifested, in the provision which he has afforded them against the winter season, to secure them from the effects of cold. Those called *herbaceous*, which die down to the root every autumn, are now safely concealed under ground, preparing their new shoots to burst forth when the earth is softened in spring. Shrubs and trees which are exposed to the open air, have all their soft and tender parts closely wrapt up in buds, which by their firmness resist all the power of frost; the larger kinds of buds, and those which are almost ready to expand, are farther guarded by a covering of resin or gum, such as the horse-chesnut, the sycamore, and the lime. Their external covering, however, and the closeness of their internal texture, are of themselves, as some say, not adequate to resist the intense cold of a winter's night: a bud *detached* from its stem, enclosed in glass, and thus protected from all access of internal air, if suspended from a tree during a sharp frost, will be entirely penetrated, and its parts deranged by the cold, while the buds on the same tree will not have sustained the slightest injury: either the detached bud must have been injured by reason of the cold entering it at the part where it was broken from the stalk; or we must attribute to the *living principle* in Vegetables, the power of resisting cold to a very considerable degree;—probably each of these is true in some measure; but how Vegetables acquire this latter-mentioned property, must be left for future observations to determine.

After the frost is moderated, and the earth sufficiently thawed, the first vital function in trees, is the *ascent of the sap*, which is taken up by the absorbent vessels composing the inner bark of the tree, and reaching to the extremity of the fibres of the roots. The water and oil thus imbibed by the roots, is there mixed with a quantity of saccharine matter, and formed into sap, whence it is distributed in great abundance to every individual bud. The amazing quantity of sweet liquid sap, provided for the nourishment of some trees, is evident from a prevalent custom in this country, of *tapping* the birch in the early part of spring; thus obtaining from each tree more than a quart of liquor, which is fermented into a species of wine. This great accession of nourishment, by means of the ascent of the sap, causes the bud to swell, to break through its covering, and to spread into blossoms, or lengthen into a shoot bearing leaves. This is the first process, and, properly speaking, is all that belongs to the *springing* or *elongation* of trees; and, in many Plants, namely, all those which are annual or deciduous, there is no other process: the Plant absorbs juices from the earth, and in proportion to the quantity of these juices increases in size; it expands its blossoms, perfects its fruit, and when the ground is incapable, by drought or frost, of yielding any more moisture, or when the vessels are not able to draw it up, the Plant perishes. But in *trees*, though the beginning and end of the first process is exactly similar to what takes place in *annuals*, yet there is a second process, which at the same time that it adds to their bulk, enables them to go on increasing through a long series of years.

This second process begins soon after the first, in this way. At the base of the foot-stalk of each leaf a small bud is gradually formed; but the absorbent vessels of the leaf, having exhausted themselves in the formation of the bud, are unable to bring it nearer to maturity: in this state it exactly resembles a seed, containing within itself the rudiments of vegetation, but destitute of absorbent vessels to nourish and evolve the embryo. Being surrounded, however, by sap, like a seed in moist earth, it is in a proper situation for growing; the influence of the sun sets in motion the juices of the bud, and of the seed, and the first operation in both of them, is to send forth the roots downwards a certain depth, for the purpose of obtaining the necessary moisture. The bud, accordingly, shoots down its roots upon the inner bark of the tree, till they reach the part covered by the earth. Winter now arriving, the cold and defect of moisture, owing to the clogged condition of the absorbent vessels, cause the fruit and leaves to fall, so that, except the provision of buds with roots, the remainder of the tree, like an annual Plant, is entirely dead: the leaves, the flowers, and fruit, are gone, and what was the inner bark is no longer organized, while the roots of the buds form a new inner bark; and thus the buds with their roots contain all that remains alive of the whole tree. It is owing to this annual renovatio of the *inner bark*, that the tree increases in bu and, a new coating being added every year, w hence furnished with an easy and exact method certaining the age of a tree, by counting the num concentric circles of which the trunk is com A tree, therefore, properly speaking, is rathe geries of a multitude of annual Plants, than nial individual. The sap in trees always rises as soon as the frost is abated, that when the stimulus of the warm weather in the spring acts upon the bud, there should be at hand a supply of food for its nourishment; and if, by any means, the sap is prevented from ascending in proper time, the tree inevitably perishes, as has been very frequently observed.

Before I conclude this Lesson, I cannot forbear saying a few words on the different manners in which Plants *disseminate their seed*. Having gone through the progressive stages of springing, flowering, and seeding, they have at length brought to maturity the rudiments of a future progeny, which are now to be deposited in the fostering bosom of the earth. Seeds are scattered by the hand of nature in various ways. Those of them which are furnished with plumes, or wings, are dispersed about by the high winds which blow soon after the autumnal equinox, the time of dissemination. Hence Plants with such seeds, are of all others, the most generally to be met ith: as dandelion, groundsel, thistles, &c. Others eans of hooks, with which they are furnished, ld of passing animals, and are thus carried to t places: the common burs are examples of ontrivance. Several when ripe are thrown ith considerable force, from their receptacle, ns of a strong spiral elastic spring; of this, *tiens*, or touch-me-not, and all the species of *cardamine*, or cuckoo-flower, are instances. Many are contained in berries, which being eaten by birds, the seeds are discharged again uninjured, and grow wherever they happen to fall. In these, and in many other ways, is the distribution of various kinds of Vegetables provided for. The shedding of the seed being finished, the parent Vegetable, if of the *herbaceous* kind, either totally perishes or withers down to the root; if a *shrub*, or *tree*, it casts all those tender leaves that in the spring and summer it had put forth: thus it continues until the following spring, when

. . .

. . . . These naked shoots
Barren as lances, among which the wind
Makes wintry music, sighing as it goes,
Shall put their graceful foliage on again,
And more aspiring, and with ampler spread,
Shall boast new charms, and more than they have lost.

COWPER.

LESSON XXXV.

ON EARTHQUAKES.

The earth shook and trembled; the foundations also of the hills moved, and were shaken, because he was wroth. DAVID.

Lo! the dire Earthquake's terrible effects!
The earth in horrid chasms is quickly op'd,
Cities and towns are into ruin hurl'd,
Whilst death and devastation spread around!
How wond'rously Omnipotent sure must be
That power who at a word can these produce!

HISTORIANS relate innumerable instances of the dreadful and various effects of those tremendous phænomena called *Earthquakes*; some of which I shall here mention. Thus, Pliny in one place, speaks of an Earthquake which happened in the reign of Tiberius, which overthrew twelve towns in Asia: in another place he mentions one, which overthrew 100 towns in Lybia. In the time of Trajan, the town of Antioch, and a great part of the adjacent country, were swallowed up by an Earthquake: also in the time of Justinian, in 528, it was destroyed by a second, together with 40,000 of its inhabitants: and sixty years after, it was visited by a third Earthquake, which destroyed 60,000 of its inhabitants. In the time of Pope Pius the 11th, all the churches and palaces of Naples were overthrown, and more than 30,000 of its inhabitants killed. In 1638 the town of Saint Euphemia was swallowed up, and there remains only a stinking lake in its place. An Earthquake happened in the island of St. Michael in the year 1691: it began on the 16th of July, and lasted until the 12th of the following month. Tercera and Fayal were agitated on the morning of the 17th with so much violence, that they appeared to move; but these frightful shocks returned only four times: whereas, as St. Michael's, they did not cease a moment for fifteen hours. The islanders, having quitted their houses, quickly saw them fall, and passed the rest of the time exposed to the injuries of the weather. A whole town, named Villa Franca, was overthrown to its very foundations, and most of the inhabitants buried amidst the ruins. Several plains rose into hills, and some mountains became flat. A spring of water issued from the earth, which flowed for four hours, and then appeared dry all on a sudden. The air and sea, still more agitated, resounded with a noise like the roaring of a quantity of wild beasts. Many persons died with the fright, and the ships in the port suffered dangerous shocks; even those which were at anchor, or under sail at the distance of twenty leagues from the island, sustained great damage.

Our deservedly celebrated poet *Cowper*, in the second book of his admirable poem THE TASK, has given us a very accurate and sublime description of the effects of *Earthquakes*, from which the following is an extract:

" The rocks fall headlong, and the vallies rise,
" The rivers die into offensive pools,
" And, charg'd with putrid verdure, breathe a gross
" And mortal nuisance into all the air:
" What solid was, by transformation strange,
" Grows fluid; and the fixt and rooted earth,
" Tormented into billows, heaves and swells,
" Or with vortiginous and hideous whirl
" Sucks down its prey insatiable. Immense
" The tumult and the overthrow, the pangs
" And agonies of human and of brute
" Multitudes, fugitive on ev'ry side,
" And fugitive in vain. The sylvan scene
" Migrates uplifted; and, with all its soil
" Alighting on far distant fields, finds out
" A new possessor, and survives the change.
" Ocean has caught the frenzy, and, upwrought
" To an enormous and o'erbearing height,
" Not by a mighty wind, but by that voice
" Which winds and waves obey, invades the shore
" Resistless. Never such a sudden flood,
" Upridg'd so high, and sent on such a charge,
" Possess'd an inland scene. Where now the throng
" That press'd the beach, and, hasty to depart,
" Look'd to the sea for safety? They are gone,
" Gone with the refluent wave into the deep—
" A prince with half his people."

There have been various hypotheses entertained with regard to the production of Earthquakes; nor does it appear an easy task to account for them with great precision. Those which are only felt at small distances are probably occasioned by the action of subterraneous fires, and the explosion of volcanos. But there have been Earthquakes which are felt at great distances, and have shaken a long course of ground: this kind of Earthquakes is by some persons accounted for in the following manner.

To understand properly what may be the cause of these phænomena, it must be remembered, that all inflammable matters capable of explosion, produce, like gunpowder, by inflammation, a great quantity of air; that this air produced by fire is in a state of very great rarefaction; and that, by a state of compression in which it is found in the bowels of the earth, it must produce very violent effects. It is then conjectured, that at a considerable depth, as at about one or two hundred fathoms, pyrites and other sulphureous matters are to be met with; and that by the fermentation produced by the filtration of water, and other causes, they inflame: the inflaming will produce a great quantity of vaporized air, the spring of which, compressed in a small space, like that of a cavern, will not only shake the earth, immediately above, but will search for passages, in order to make its escape. It will therefore naturally force its way through those parts where it meets least obstruction, and will proceed through any channels or caverns through which it can find a passage. This subterraneous air or vapour will alſo produce in its passage a noise and motion proportioned to its force and resistance it meets with: and these effects will be continued 'till it finds a vent, perhaps in the sea, or till its force be diminished by being greatly expanded. This explanation corresponds entirely with all the phænomena that are observed respecting Earthquakes: for they proceed with a wave-like motion, and are felt at different places, not at the same instant, but at different times in proportion to the distance.

Yet, plausible as the above hypothesis may appear, it is objected to by several of the modern philosophers, who in opposition thereto, assert, that Earthquakes are produced by an accumulation of the electric fluid in the bowels of the earth.

Mr. *Nicholson*, in his *Introduction to Natural Philosophy*, says, " It is extremely probable, that " Earthquakes owe their original to the discharge " between a cloud and the earth, in a highly elec- " tric state, or even between two clouds." In support of this opinion he advances the following arguments:—" They happen most frequently in dry " and hot countries, which are most subject to " lightning and other electrical phænomena; and " are even foretold by the electric coruscations and " other appearances in the air, for some days pre- " ceding the event. Earthquakes are attended by "no fire, vapour, or smell, which however could "hardly fail to appear, if the common opinion, of "their being occasioned by a subterraneous explosion, were true. The effect of an explosion "of this nature would be a gradual lifting of the "earth, after which it would fall again, and, no "doubt, destroy or change the course of springs, "and considerably alter the face of the country; "the contrary to which is true; for, as far as observation can determine, the shock of an Earthquake is instantaneous to the greatest distances, "and seldom does more mischief than overthrowing buildings. Earthquakes are usually accompanied by rain, and sometimes by the most dreadful thunder-storms. All these, and many more "circumstances, but especially the almost instantaneous motion of the shock, induce us to look "for their cause in electricity, the only power in "nature that acknowledges no sensible transition "of time in its operations." Against this reasoning it has been objected, that if the accounts which historians have transmitted us of Earthquakes in the last Century, be correct, the circumstances attending these awful events are, frequently, widely different from what Mr. Nicholson supposes them to be. At present, each of these disagreeing hypotheses has many advocates, though that which Mr. Nicholson supports seems to be gaining ground:—however, whether Earthquakes be produced by the explosion of sulphureous matters, or by the power of the electric fluid, we may safely infer, that the natural cause of their production is inherent in the earth. Hence the contemplative young reader will conclude, that we might be continually in expectation of the whole earth being destroyed by this invisible agent of nature; if we were not certain that it is always managed by a wise and good, as well as powerful, BEING, who keeps it safely curbed, or gives it liberty to range, as it may by HIM be thought most suitable to his divine purposes.

LESSON XXXVI.

ON VOLCANOS.

The dread Volcano ministers to good:
Its smother'd flames might undermine the world.
Loud Ætnas fulminate in love to man. YOUNG.

A WONDERFUL appearance on the face of nature which we have not yet reflected upon, is a *burning mountain*, or *Volcano*, to describe which in the manner it deserves would almost surpass the power of words. A Volcano contains in its bowels, sulphur, bitumen, and other materials which serve as food to a subterraneous fire, the effects of which are more violent than those of gunpowder, or even of thunder: hence a Volcano has been sometimes compared to a cannon of a very large size. The orifice or mouth of a Volcano is, in some cases, more than a mile across: and from this mouth are emitted torrents of smoke and flame; rivers of bitumen, sulphur, and melted metal, the mixture bearing the name of *lava*; clouds of cinders and stones, and sometimes it ejects enormous rocks to many leagues distance, when merely to stir them would baffle the utmost efforts of human strength. The combustion is so terrible, and the quantity of burnt, melted, calcined, and vitrified materials which is thrown out at the orifice, is so plentiful, that they enter towns and forests, cover the fields to more than an hundred feet in thickness, and sometimes form hills and mountains. The action of this fire is so great, and the force of explosion so violent, that its reaction has been known to shake the earth, agitate the sea, overthrow mountains, and raise the most solid edifices and towns, even to very considerable distances.

A mixture of sulphur, filings of iron, and of water, buried at a certain depth below the earth's surface, will exhibit, in miniature, all the appearances of a Volcano: hence we are induced to conclude, that in the bowels of burning mountains, there are different kinds of inflammable substances, which ferment when acted upon by peculiar means, (probably by moisture,) and produce eruptions and explosions, of different degrees of strength, according to the quantity of inflammable matters accumulated.

In Europe there are three famous Volcanos, namely, *Mount Ætna* in Sicily, *Mount Hecla* in Iceland, and *Mount Vesuvius* in Italy, near Naples. There are several Volcanos also in various parts of Asia and America, some of which at intervals emit their burning contents with great violence. Of each of the burning mountains in Europe I shall here present you with some account.

From Mount Ætna the eruptions of flame and smoke are discovered at a great distance, by those who sail on the Mediterranean, even as far as the harbour of Malta, which is more than 40 leagues from the shore of Sicily. Though fire and smoke are continually vomited up by it, yet at some particular times it rages with greater violence. In the year 1536 it shook all Sicily, from the first to the twelfth of May; after that there was heard a most horrible bellowing and cracking, as if great guns had been fired: there were a great many houses overthrown throughout the whole island. When this storm had continued about eleven days, the ground opened in several places, and dreadful gapings appeared here and there, from which issued forth fire and flame with great violence, which in four days consumed and burnt up every thing that was within five leagues of Ætna. A little after, the funnel, which is on the top of the mountain, disgorged a great quantity of hot embers and ashes, for three whole days together, which were not only dispersed throughout the whole island, but also carried beyond sea to Italy; and several ships that were sailing to Venice, at two hundred leagues distance, suffered damage. *Facellus*, who has given an historical account of the eruptions of this mountain, says, that the bottom of it is one hundred leagues in circuit.

Mount Hecla, rages sometimes with as great violence as Ætna, and casts out large stones. The imprisoned fire often, for want of vent, produces horrible sounds like lamentations and howlings; which makes some credulous and superstitious people think it the place of hell, where the souls of the wicked are tormented.

The declivity of Mount Vesuvius towards the sea, is every where planted with vines, and fruit trees, and it is equally fertile towards the bottom. The circumjacent plain affords a delightful prospect, and the air is clear and wholesome. The south and west sides of the mountain form very different views; being, like the top, covered with black cinders and stones: the height of this mountain has been computed to be about 3900 feet above the surface of the sea. Vesuvius has been a volcano, beyond the reach of history and tradition: but there are on record more than 30 eruptions which have taken place since the one that destroyed the city of *Herculaneum*, in the time of Titus; some of these have been very furious and violent, desolating the country for miles around; and ships at sea, at the distance of threescore miles, have in some of these eruptions been covered with cinders, to the astonishment of the sailors.

"Few things in nature are so absolutely noxious "as not to produce some good." This observation is completely verified in the instance before us: for even this raging Volcano, by its sulphureous and nitrous manure, and the heat of its subterraneous fires, contributes greatly to the uncommon fertility, in fruits and herbage, of the country about it.

Dr. *Woodward* mentions the existence of Volcanos as a special favour of Providence, and says; "There are scarcely any countries that are much "annoyed with earthquakes, that have not one of "these fiery vents. And these are constantly all "in flames whenever any earthquake happens, they "disgorging that fire, which, whilst underneath, "was the cause of the disaster. Indeed," saith he, "were it not for these *diverticula*, whereby it "thus gaineth an *exit*, it would rage in the bowels "of the earth much more furiously, and make "greater havoc than now it doth. So that though "those countries, where there are such Volcanos, "are usually more or less troubled with earthquakes; yet, were these Volcanos wanting, they "would be much more annoyed with them than "now they are; yea, in all probability to that "degree, as to render the earth, for a vast space "around them, perfectly uninhabitable. In one "word, so beneficial are these to the territories "where they are, that there do not want instances "of some which have been rescued from earthquakes by the breaking forth of a new Volcano "there; this continually discharging that matter, "which being till then barricaded up, and imprisoned in the bowels of the earth, was the "occasion of very great and frequent calamities."

Let me then be permitted to observe in this place, that though we cannot, in every case, see the beneficent tendency of particular creatures and things in the universe, we ought to attribute this to our limited capacities; and not arraign ALMIGHTY SOVEREIGNTY, as is the custom with too many carping philosophers of the present day. However dreadful and destructive subterraneous fires may appear; on proper reflection it may be inferred, that they are as necessary in promoting and sustaining the operations of this part of the universe, as the natural heat in men's bodies, is to the preservation and support of their being.

As every body possesses inherently the principles of its own dissolution, it is by many wise and learned men imagined that the *general conflagration* may at last be brought about by means of these fires: amongst the natural means of causing it we are acquainted with, some persons embrace the opinion here mentioned, whilst others are inclined to think the effect will be produced by comets; but though finite creatures may conjecture on this subject, it is most probable that it will never be ascertained by mortals.

LESSON XXXVII.

ON THE EYE.

In the materials of the human frame,
What num'rous wonders might we quickly name!
Let it suffice that I describe a few,
And treat my readers with a short review.

WE will now extend our contemplations to the
uman *fabric*; and here the science of *Anatomy*
scovers to us ten thousand beauties which the
rrow limits I have prescribed myself render it
possible to mention: indeed it would not be pos-
le, in a performance of this kind, to explain
equately the geometrical accuracy with which
e AUTHOR OF NATURE has formed every part
the body to carry on the animal œconomy, and
swer the various purposes of life. All I propose
perform in this and the two following Lessons,
by touching upon the nature and wonders of the
ye, of *Concoction*, and of the *Circulation of the*
ood, to give my young readers some little insight
o these matters, as an inducement for them to
apart a portion of their leisure time for the pur-

pose of acquiring a farther acquaintance with *an tomy*.

And first for a short description of the *organ* *Sight*, that noble instrument, which

——Takes in at once the landscape of the world,
At a small inlet which a grain might close,
And half creates the wond'rous world we see. YOU

The Eye is in form nearly globular; it consi of three coats and three humours. The part of th outward coat hid from our sight is called the *Scl rotica:* the front part, which rather projects o the *Cornea:* the next within this coat is that call the *Choroides*, which serves, as it were, for lining to the other; in the front it joins with th part known by the name of the *Iris*, because it in different persons of different colours, as bl brown, green, &c. The *iris* is composed of t sets of muscular fibres; the one, of a circular for which contracts the hole in the middle called t *pupil*, when the light would otherwise be too stro for the Eye; and the other, of radial fibres, te ing every where from the circumference of the i towards the middle of the *pupil*; these by th contraction dilate and enlarge the *pupil*, when t light is weak, in order to admit more rays. T third coat is only a fine expansion of the optic ne which spreads like net-work all over the inside the *choroides*, and is therefore called the *retin*

up

pon it are in a manner painted the images of all
sible objects, by the rays of light which either
ow or are reflected from them.

Immediately under the *cornea* is a fine transparent
id, like water, which is therefore called the *aque-*
s humour: it gives a protuberant figure to the
rnea, and has the same limpidity and refractive
wer as water. At the back of this, lies a hu-
our transparent like crystal, and is much of the
nsistence of hard jelly: it is shaped like a double
nvex glass, and is a little more convex on the
ck than on the fore part; it is named the *crys-*
lline humour, and is of service in converging the
s which pass through it, to its focus at the bot-
n of the Eye. This humour is enclosed in a fine
nsparent membrane from which proceed radial
es called the *ligamentum ciliare* all around its
ge, joining to the circumference of the *iris*. These
es have a power of dilating and contracting oc-
ionally, by which means the convexity of the
stalline humour, is altered; and it is also
reby shifted a little backward or forward in the
e, so as to adapt its focal distance at the bottom
reof to the different distances of objects: with-
which provision we could only see objects dis-
tly at one particular distance from the Eye.

t the back of the *crystalline*, lies the *vitreous*
nour, which is transparent like glass, as its name
otes, and is largest of all in quantity; filling
rest of the Eye, and giving it a globular shape:

it is much of the consistence of the white of an eg its refractive power very little exceeding that water.

As rays are emitted or reflected from every point an object, some of these from the side next the E will fall upon the *cornea*, and by passing on throu the *pupil* and different humours will be converged various points on the *retina* at the bottom of Eye, and will thereon form an inverted picture the object; if this inverted image be not formed, object cannot be seen: when, unfortunately, of the parts of the Eye are so injured as to lose transparency, the person becomes blind.

But it is not sufficient in order to our se objects, that their images should be painted on retina; some persons, it is said, are blind, tho this takes place. Hence we see, that images pa on the retina, are not the immediate object of vi and that the perception of the soul is communic some other way. The small nerves of the re (it is now generally admitted,) are agitated by rays of light which form the image at the bo of the Eye; and this agitation is transmitted by optic nerve to the brain. It is there the m perception is formed; but the most dextrous tomist is unable to pursue these nerves to source; the union of the soul with the body probably for ever remain a mystery.

There is an astonishing apparatus of m wherewith the Eye is furnished, to produce al

nece

necessary and convenient motions; among these I cannot help alluding to that admirable contrivance by which the pupil is contracted or dilated, according as vision requires. This variability of the pupil is essentially necessary to vision: for, if a contraction were not to take place when the Eye was brought into a very luminous situation, the great number of rays which would enter therein, would probably much injure the fine contexture of nerves at the bottom of the Eye, on which the images of bjects are pourtrayed; and, if the pupil did not expand when the Eye was in a dark place, the few eeble rays which would enter the Eye, would not orm any impression on the retina. Hence it is a ery remarkable and providential circumstance, that he change in the pupil should take place almost pontaneously, and independent of any act of the will.

Distance is only conceived from experience, and he more distant an object is, the less it appears: hen therefore, from certain circumstances, we annot form a just conception of distance, and when e cannot judge of objects but by the image which pourtrayed in our Eyes, we are then necessarily eceived as to their size. Thus every person must e aware how liable we are, in travelling by night, mistake a distant tree for a bush that is near, a bush near at hand for a tree at a distance. In e same manner if we do not distinguish objects their shape, and by it also judge of distance, the fallacy is likely to continue: in this case, a fly, which may pass before us with rapidity, will seem to be a bird at a considerable distance; and a horse, which may be in the middle of a plain, not moving, and in an attitude similar, for instance, to that of a sheep, may in the dusk appear in every sense like a sheep.

If, therefore, we are benighted in a strange place, where no judgment of distance can be formed, we are every moment liable to deceptions of vision. Hence originate most of the dreadful stories of spectres, and of those wonderful, hideous, and gigantic figures, which many persons speak of having seen. Though it is commonly asserted, that such figures exist solely in the imagination; yet it is highly probable, that they might appear to the Eye in every respect as described. This remark will be allowed to have the greater force, when it is considered, that if the size of an object be generally judged of by the angle which it forms in the Eye, it is magnified according to its propinquity; of course, if it seemed at first to the spectator (wh is equally incapable of distinguishing what he see and of judging at what distance it is,) a few fe high, when at the distance of thirty or forty yard from him; it must look to him, when he is withi a few feet of it, of a size stupendously encreased At this he will naturally be terrified, unless h touch and thus distinguish the seemingly enormo object; for in the instant he has an actual percep

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tion of what it is, the enormity will diminish, and the object will appear in its real state : if, on the other hand, he be afraid to approach it, and flies from the spot with precipitation, the only idea remaining of what was presented to his view, will be that of an image, gigantic in its size, and horrible in its form. The prejudice about spectres and hobgoblins, therefore, in some degree originates from nature, and such visionary objects depend not entirely on the imagination alone, as has been frequently supposed.

If room would permit it would be a pleasing employment to point out many advantages which arise from the form, the size, the motions, and the situation of the Eye, each of which has a tendency to evince the wisdom and goodness of the omnipotent Creator. But this has been well done by Mr. *Derham*; to whose "*Physico Theology*" I must refer you. The celebrated *Euler* in his "*Letters to a German Princess*," points out an astonishing difference between the human Eye, and any artificial eye which can be constructed: he then makes some admirable reflections, part of which I now lay before you. "The Eye which the Creator has
" formed, is subject to no one of all the imperfec-
" tions under which the imaginary construction of
" the freethinker labours. In this we discover the
" true reason, why infinite wisdom has employed
" several transparent substances in the formation of
" the Eye: it is thereby secured against all the defects
" which characterize every work of man. What

“ a noble subject of contemplation! *He who formed the Eye, shall he not see? and he who planted the ear, shall he not hear?* The Eye alone being a master-piece that far transcends the human understanding, what an exalted idea must we form of him, who has bestowed this wonderful gift, and that in the highest perfection, not on man only, but on the brute creation, nay, on the vilest of insects!”

Indeed, if we do but reflect upon the many diversified and beautiful scenes which are made visible to us by means of the organ of Sight, and consider the deplorable state, and the many inconveniencies those persons lie under, who are deprived of this blessing, our hearts ought to overflow with thankfulness to that kind BEING who has bestowed so useful an instrument as the Eye upon us, to add to our convenience and delight; and whose superintendency protects it from those injuries which are continually liable to befal it.

LESSON XXXVIII.

ON CONCOCTION.

——The concoctive powers with various art,
Subdue the cruder aliments to chyle;
The chyle to blood; the foamy purple tide
To liquors, which thro' finer arteries
To different parts their winding course pursue.

ARMSTRONG.

AMONG all the wise contrivances observed in the human fabric, none can excite our attention and admiration more than the disposition and mechanisms of those parts, by which our aliment is concocted, or fitted for our daily support and nourishment.

To have a clear idea of the manner in which *Concoction* is performed, we must distinguish it into three stages: the first of which is performed in the progress of the aliment from the mouth down to the lacteal veins; which are vessels that receive the chyle from the intestines: the second is performed in the passage of the milky liquor called chyle, through the lacteal vessels to the loins, and then up under the collar-bone, where it mingles with the blood: the third, or ultimate stage of Concoction, is performed by the circulation of the blood and chyle together through the lungs, and the whole arterial system. In all these stages the design of the GREAT ARCHITECT has evidently been to grind and dissolve the aliment, and to incorporate it with a large quantity of animal juices already prepared, in such a manner as to reduce it at last to the very same substance with our blood and humours. How wonderfully and completely this design has been executed, my young readers will presently be able to judge.

In the first stage of Concoction, by a curious configuration of parts, and action of muscles, adapted to their respective functions, our food is ground small by the teeth, and moistened by a copious saliva in the mouth. It is in the next place swallowed, and conveyed down the gullet, where it is farther mollified and lubricated by a viscid unctuous humour, distilled from the glands of that canal. From thence it slips into the stomach, where several causes concur towards its complete dissolution. It is diluted by the juices, swelled and subtilized by the internal air, and it is macerated and dissolved by the heat which it meets with in the cavity. It is also agitated and attenuated by the perpetual friction of the coats of the stomach, and the pulsation of the arteries there; by the alternate elevation and depression of the diaphragm or midrif in breathing; and by the compression of the strong muscles of the belly. After a proper stay, it is gradually propelled into the intestines, in the form of a thick, smooth, uniform, ash-coloured fluid.

When our aliment, thus prepared, arrives at the intestines, it is there mixed with three different sorts of liquors. It receives two kinds of bile; the one, thick, yellow, and extremely bitter, from the gall-bladder; the other, scarcely bitter or yellow, but in a much larger quantity, from the liver. The third liquor that falls here upon the food, issues plentifully from a large glandular substance, called the pancreas or sweet-bread, and is a limpid mild fluid, like the saliva, which serves to dilute and sweeten what may be too thick and acrimonious. The two saponaceous biles resolve and attenuate viscid substances; incorporate oily fluids with aqueous ones, making the whole mixture homogeneous; and by their penetrating and detergent qualities render the chyle fit to enter the lacteal veins, into which it is conveyed, partly by their absorbent nature, and partly by the peristaltic motion of the intestines.

If we now consider the change which our aliment has undergone, in the mouth, gullet, and stomach, together with the large quantity of bile, and pancreatic juice poured upon it in the intestines: and if we reflect also on the incessant action of the muscles, blending, churning, and incorporating the whole, we shall readily perceive that their united agency must alter the flavours and properties of the different kinds of food, in such a manner as to bring the chyle nearer in its nature to our animal juices, than to the original substances from which it was formed. Our food thus changed into chyle, constitutes the first stage of Concoction; and we shall find the same assimilation carried on through the second.

The next stage begins with the slender lacteal veins, where they arise from the intestines by an innumerable multitude of invisible pores, through which the fine, white, fluid part of the chyle is strained or absorbed; while, at the same time, the gross, yellow, fibrous part, conveyed slowly forward, and further attenuated in the long intestinal tube, is perpetually pressed and drained of its remaining chyle, until the dregs, becoming at last useless, are ejected out of the body.

These lacteal veins issue from the intestines in various directions, now straight and then oblique, often uniting and growing larger, but presently separating again. They frequently meet at acute angles, and enter into soft glands dispersed through the mesentery, from which they proceed larger than before, and more turgid, with a fine lymphatic fluid: in most places also they run contiguous with the mesenteric arteries, by whose pulsation their load is pushed forward. And thus, after various communications, separations, and protrusions, the lacteal veins pour their chyle into a sort of cistern or reservoir formed for that purpose, between the lowest portion of the diaphragm and the highest vertebre of the loins. It is very remarkable that these veins are furnished with proper valves, which permit the chyle to move forward, but effectually stop its return; and that a great number of veins purely lymphatic, as well as the lacteal ones, empty themselves into the same cistern.

In all this contrivance it is evident, that the chyle, being more and more diluted and blended with abundance of lymph from the glands through which it passes, and from other sources, approaches still nearer to the nature of our animal juices, and consequently becomes more fit for nutrition.

The chyle is pushed from its reservoir into a narrow transparent pipe, called the thoracic duct, which climbs in a perpendicular direction by the side of the back-bone, from the loins up to the collar-bone, and opens into the subclavian vein; where, by the peculiar arrangement of several small valves, the chyle mingles gently with the blood after it has been thoroughly elaborated; and attenuated with lymph from every part of the thorax, or great cavity of the breast, and is from thence soon conveyed to the heart.

Thus we may perceive that by a wonderful mechanism, a large quantity of chyle and lymph is forced upwards, in a perpendicular course, through a thin slender pipe; but to render this more plain, the following particulars must be attended to:—First, to the progress of the chyle, urged forward and continued from the antecedent action of the intestines, and the beating of the mesenteric arteries. Secondly, to the motion of the diaphragm and lungs, in respiration, pressing the thoracic duct that lies under them, whilst the thorax rising and falling resists their action, whereby the duct is squeezed between two contrary forces, and the liquor which it contains pushed upwards. Thirdly, this duct runs close by the side of the great artery (called by anatomists, the superior portion of the descending aorta) whose strong pulsation presses its yielding sides, and compels the chyle and lymph to mount in an upright ascent; Fourthly, it must be observed, that this duct is accommodated with valves, which permit its contents to move upwards by every compression, but never to fall back again.

Thus terminates the second stage of Concoction, when the chyle falls into the heart. And it may be seen that in the progress through these two stages, our aliment has been mixed accurately with all the nourishing juices and with all the substances or principles which compose the blood, viz. saliva, mucus, lymph, bile, water, salts, oil and spirits.

But here it will be proper to take notice, that the most fluid and subtile parts of our aliment, before and after it is elaborated into chyle, passes into the blood by certain absorbent veins dispersed all over the mouth, gullet, stomach, and intestines: when we consider how quickly refreshment and strength are communicated to weary, faint, and hungry people, immediately upon drinking a glass of good wine, or eating any cordial spoon-meat, this remark will appear the more obvious.

The third stage begins where the chyle mingles with the blood, and falling soon into the right ventricle of the heart, is from thence propelled into the lungs. It will appear that the lungs are the principal instruments of converting the chyle into the blood; especially if we consider their structure, first with regard to the air-vessels of which they are composed, and secondly with regard to their blood-vessels: for we shall then clearly perceive the change which their fabric and action must produce on the chyle.

The windpipe is composed of segments of cartilaginous rings on the fore part, to give a free passage to the air in respiration; and of a strong membrane on its back part, to bend with the neck, and give way to the gullet in deglutition. This pipe is lined throughout with an infinity of glands, which perpetually distil an unctuous dense humour to lubricate and anoint the passages of the air. Soon after the windpipe has descended into the cavity of the breast, it is divided into two great branches, and these two are subdivided into innumerable ramifications called bronchia, which grow smaller in their progress, (not much unlike a bushy tree inverted) until at last they terminate in millions of little bladders which hang in clusters at their extremities, and are inflated by their admission of air, and subside at its expulsion. These clusters constitute the lobes of the lungs.

The blood-vessels of the lungs next deserve our attention. The branches of the pulmonary artery run along with those of the windpipe, and are ultimately subdivided into an endless number of capillary ramifications, which are spread, like a fine net work, over the surface of every individual air bladder: and the pulmonary vein, whose extreme branches receive the blood and chyle from those of the arteries, run likewise in form of a net over all the air-bladders of the bronchia.

From this admirable structure of the lungs, it is obvious, that the crude mixture of the blood and chyle, passing through the minute ramifications of the pulmonary artery and vein, is compressed and ground by two contrary forces, viz. by that of the heart, driving the mixture forward against the sides of the bronchia and air bladders; and by the elastic force of the air equally repelling this mixture from the contrary side.

By these two opposite forces the chyle and blood are more intimately blended and incorporated; and by the admission and expulsion of the air in respiration, the vessels are alternately inflated and compressed (and probably some subtile air or æther is received into the blood) by which means the mixture is still farther attenuated and dissolved; and after various circulations through the lungs and heart, and the whole arterial system, is at last perfectly assimilated with the blood, being fitted to nourish the body; and answer the different purposes of animal life.

When ~~the blood thus prepared from the~~ aliment, is by repeated circulations gradually drained of all its bland and useful parts, and begins to acquire too great a degree of acrimony, it is carried off by both sensible and insensible evacuations, through the several channels and distributions of nature. By these evacuations the body is made languid, and requires a fresh supply of aliment; while at the same time the saliva, and juices of the stomach and intestines, growing thin and acrid by multiplied circulations, vellicate the nerves of those passages, and excite hunger, as a faithful monitor, to remind us of that refreshment which is now become necessary. And here I take my leave of the process of Concoction: in the consideration of which the young reader will find abundant cause for astonishment and admiration.

LESSON XXXIX.

ON THE CIRCULATION OF THE BLOOD.

The Blood, the fountain whence the spirits flow,
The gen'rous stream that waters ev'ry part;
And motion, vigour, and warm life conveys
To ev'ry particle that moves or lives. ARMSTRONG.

THOUGH it be common to talk familiarly of the *Circulation of the Blood*, yet perhaps very few of my young readers are well acquainted with it: I shall therefore appropriate this Lesson to the purpose of giving them a brief, though I hope intelligible, description of the manner in which the Circulation is performed. This important secret was brought to light by *William Harvey*, an English physician, a little before the year 1600: and when it is considered thoroughly, it will appear to be one of the most stupendous works of OMNIPOTENCE.

To form a distinct judgment of the mechanism and importance of the Circulation, it will be necessary to describe the structure of the arteries, veins, and nerves; and take notice of some experiments made upon them; and then, must be considered the cavities of the heart, by means of which the Blood is propelled through the body: to which I now proceed.

The arteries are blood-vessels consisting of a close texture of strong elastic fibres, woven in various webs, laid in different directions, and interspersed with an infinity of delicate nerves, veins, and minuter arteries. They are divided and subdivided into numberless branches and ramifications, that grow smaller and smaller as they recede from the heart, until at last their extremities become much more slender than the hairs of our heads, (and are therefore called capillary arteries) which are found either to unite in continued pipes with the beginnings of the veins, or to terminate in small receptacles, from which the veins derive their origin. The arteries have no valves, but only have their trunks spring from the heart: they throb and beat perpetually whilst life remains; their extremities differing in the thickness of their coats and some other particulars, according to the nature of the part which they pervade. All the arteries in the lungs (except the small ones that convey nourishment to them) are derived from the great pulmonary artery, which issues from the right ventricle of the heart. And all the arteries in the rest of the body proceed from the aorta (which obtained this name, because the antients thought it contained air only) whose trunk springs from the left ventricle of the heart.

The veins resemble the arteries in their figure and distribution, but their cavities are larger, and their branches, perhaps, more numerous. Their coats are much weaker and more ſlender than those of the arteries. They are furnished with several valves, contrived in such a manner as to permit the blood to pass freely from the smaller into the larger branches, but stop its retrogression. They neither throb nor beat. Their beginnings form continued pipes with the extremities of the arteries, or arise from some gland or receptacle where the arteries terminate. All the veins in the lungs, from their capillary beginnings growing still larger, unite at last and discharge their blood into the left auricle of the heart: and all those in the rest of the body empty themselves in like manner, into the vena cava; which opens into the right auricle of the heart.

The nerves deduce their origin from the brain, or its appendages, in several pairs, of a cylindric form, (like so many skeins of thread with their respective sheaths,) which in their progress decrease by endless divisions and subdivisions, until at last they spread themselves into a texture of filaments, so slender, and so closely interwoven with each other over the whole body, that the point of a needle can hardly be put upon any part of it, without touching the delicate branch of some nerve.

It has been found by many trials, that when an artery is laid bare, and a ligature made upon it, if it be opened with a lancet between the ligature and the heart, the blood will rush out with great violence; and a rapid, jerking stream will continue (if it be not stopped by art) until, through loss of blood, the animal faints or dies. But if the same artery be opened between the ligature and extremities, a few drops only will ooze out from the wounded coats thereof.

On the other hand, when a vein is laid bare, and a ligature made upon it, if it be opened between the ligature and the extremities, the blood will gush out, as we see in common venesection. But if the same vein be opened between the binding and the heart, no blood will appear. From these experiments it is obvious to the slightest attention, that the blood flows from the heart, through the arteries, to the extreme parts of the body; and returns again through the veins to the heart.

For the regular performance and continuation of this motion of the blood through all the different parts of the body, the wise ARCHITECT has furniſhed the heart, which is the *primum mobile*, giving the first impulse, with four distinct muscular cavities, that is, with an auricle and a ventricle on the right side, and an auricle and a ventricle on the left. Through these cavities, curiously adapted to their respective offices, the blood circulates in the following order:—It is received from the veins, first into the right auricle, which contracting itself, pushes the blood into the right ventricle at that instant dilated. The moment this ventricle is filled it contracts itself with great force, and impels the blood into the pulmonary artery, which passing through the lungs, and returning by the pulmonary veins, is received into the left auricle of the heart, and from thence it is pushed into the left ventricle: which being thus filled, contracts itself, and drives the blood with great rapidity to all the parts of the body, and from them it returns again through the veins into the right auricle of the heart, as before.

It is very remarkable, that we have here a double Circulation: one, from the right ventricle, *through the lungs*, to the left auricle of the heart, in order to convert the chyle into blood, and finally prepare it for the nourishment of the animal. The other, from the left ventricle, *through the whole body*, to the right auricle of the heart, which serves to apply that nourishment to every part, besides various other purposes.

But to proceed. Of these four muscular cavities, the two auricles are contracted at the same instant, while the two ventricles are dilated; the ventricles, in their turn, are contracting themselves at the very instant that the auricles are dilating. The arteries, in like manner, beat in alternate time with the ventricles of the heart.

The nerves, as well as the veins and arteries, act their part in this rotation of the Blood; for if the eighth pair of nerves which proceeds from the brain to the heart be bound up, the motion of the heart immediately languishes, and soon ceases entirely.

Thus we have a species of *perpetual motion*, which none but a Being of infinite wisdom and power could produce; and probably its continuation requires the constant aid of the same hand that first gave it existence. The brain transmits animal spirits to the heart, to give it a vigorous contraction. The heart, at the same instant, pushes the Blood into the brain to supply it with new spirits; by which means the head and the heart give continual mutual support to each other. But this is not all; the action of the heart sends the Blood and other vital humours over the whole body by the arteries, and distributes nourishment and vigour to *every part*, (while perhaps the animal spirits, from the extremities of the nerves, return again into the Blood) and the whole refluent mass is conveyed back through the veins into the heart, which enables it, without intermission, to persist in rolling this *tide of life*.

But here it must not be supposed, that the arteries pass on to the extremities of the limbs, before they communicate with the returning veins: for upon this supposition, after an amputation has been performed, whatever Blood might be brought to the stump by the arteries, it is certain, none of it could be carried back again to the heart; because the intercourse between the heart and the limbs would, in this case, be entirely cut off. But the all-wise Author of our being has provided for this exigency, by forming a great number of less branches from the larger arteries, which constantly communicate with corresponding branches of the returning veins. And hence, it is easy to conceive, how the Circulation is carried on, after amputation has been performed *.

From what little has been advanced in this and the two preceding Lessons, the unprejudiced young reader will find a striking display of the wisdom and goodness of our CREATOR. To those who still hold to the negation of such a being, I scarcely know what to say: for they who live, move, think, and act, must be left without excuse, if they deny or forget GOD, or refuse to honour and be thankful to him. Those who withstand the evidence of the works of nature, when properly observed, are not likely to be convinced by rational deductions; but will probably continue infidels (unless their hearts be changed by divine grace) until they are convinced of their fatal mistake, by experiencing the indignation of that ALMIGHTY BEING, whose existence they have so impiously denied.

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* With respect to the velocity of the circulating blood, and the time in which the whole quantity thereof has undergone a complete circulation; although several computations have been made, the matter is not decisively settled. Dr. *Jurin* and Dr. *Keill*, have most distinguished themselves in inquiries of this nature; but they are far from agreeing in their conclusions: the substance of their calculations and experiments may be seen in Dr. *Rees*'s improved edition of CHAMBERS'S CYCLOPÆDIA, under the articles *blood* and *heart*.

But this, I sincerely hope, will not be the case with any of the youthful perusers of these Lessons: however in this sceptical age, when every part of divine truth is questioned, opposed, and alas! too frequently holden in derision, it becomes us to be wary; and not only so, but to join in a general endeavour to persuade those who are deviating from the true path, speedily to return thereto.

Come! all ye nations! bless the LORD,
To him your grateful homage pay:
Your voices raise with one accord,
JEHOVAH's praises to display.

From clay our complex frames he moulds,
And succours us in time of need:
Like sheep when wandering from their folds
He calls us back, and does us feed.

Then thro' the world let's shout his praise,
Ten thousand million tongues should join,
To heav'n their thankful incense raise,
And sound their MAKER's love divine.

When rolling years have ceas'd their rounds,
Yet shall his goodness onward tend;
For his great mercy has no bounds,
His truth and love shall never end!

LESSON XL.

CONCLUDING REMARKS AND ADVICE.

Ye guardian powers, who make mankind your care,
Give me to know wise nature's hidden depths,
Trace each myſterious cause, with judgment read
Th' expanded volume, and submiss adore
That great creative will, who at a word
Spoke forth this wond'rous scene. SOMERVILLE.

WHEN we consider the contracted and confined nature of human knowledge, even in its present improved state, we must not anticipate to ourselves the pleasure of obtaining such a degree of philosophic ſkill, as is described in the above-cited lines of the poet: for it may be recollected that, when endeavouring to elucidate the causes of some of the grand phænomena of nature, we more frequently proceeded upon conjecture and hypotheses, than upon any real and permanent foundation. However, though this be admitted, it must not be concluded therefrom that we should be entirely inattentive to philosophic speculations; for contemplations of this kind, when properly regulated, have a tendency to correct wrong opinions, which we might otherwise entertain of the wisdom and goodness of that BEING who created the universe.

It is in conformity to this idea, that I have in the foregoing Lessons attempted to describe to you the nature and supposed causes of some few of the numerous objects and appearances in creation: and I hope that, even from the descriptions which I have given, faint and imperfect as they must be acknowledged to be, I shall be justified in adopting the language of Mr. *Cotes* when he says, "That man "must be blind, who, from the most wise and "excellent disposal of things, cannot immediately "perceive the infinite wisdom and goodness of the "Almighty Creator; and he must be mad, who "refuses to acknowledge them."

I have, in the course of these Lessons, frequently referred you to such works of eminent writers, as may be consulted with advantage; I shall now, previous to drawing a conclusion, mention some other authors in whose works you may meet with more information; not only on the subjects treated upon in this performance, but on several, which the narrow limits I am confined to, have hindered me from even mentioning.

On *Anatomy* I would recommend the works of *Borelli*, *Harvey*, *Hunter*, *Jurin*, *Keill*, *Motherby*, and *Nieuwentyt*. On *Astronomical* subjects, *Bonnycastle*, *Bryan*, *Emerson*, *Ferguson*, *Gregory*, *Keill*, *Long*, *Maskelyne*, *Vince*, and *Wales*, are writers of distinguished reputation. The best writers on *Electricity*, are *Brooks*, *Cavallo*, *Ferguson*, *Franklin*, *Morgan*, and *Priestley*. On *Optics*, the performances of *Harris*, *Martin*, NEWTON, *Smith*, and *Wood*, will particularly merit your attention. Various other parts of Philosophy, or *Natural Philosophy* in general, may be found treated on, either in a popular or scientific way, in the works of *Desaguliers*, *Emerson*, *Enfield*, *Ferguson*, *Gregory*, *Keill*, *Martin*, *Mariotte*, NEWTON, *Nicholson*, *Nieuwentyt*, *Rowning*, *Rutherforth*, and *Ryland*. There has also been lately issued into the world, a Dictionary, by my highly esteemed friend, Dr. *Charles Hutton*, of *Woolwich*, in which abundant information on astronomical, mathematical, and philosophical subjects may be met with. I would also recommend to your notice the periodical publications in which philosophical and mathematical questions are discussed: the principal of these are, the *Ladies Diary* and *Supplement*, *Gentleman's Diary*, *Scientific Receptacle*, *Mathematical Repository*, and the *Student*; besides monthly productions, several of which are worth notice.

Above all, I must entreat my young readers early to imbibe religious principles *: for it is religion only that can regulate the heart,—it causes it to melt in sympathy at another's distress, or to glow with pleasure at another's happiness,—it is this alone that can harmonize the mind,

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* "With the talents of an angel a man may be a fool: if he "judge amiss in the *supreme point*, judging aright in all else but "aggravates his folly, as it shews him wrong, though blest with "the best capacity of being right." DR. YOUNG.

> "Attuning all it's passions into peace."

The astronomer, if enlightened by it, must contemplate, with wonder and admiration, those luminaries on which his eye so often gazes with pleasure. The philosopher too, when the wonders of nature are open to his view, with what adoration and gratitude must he look to that great source from whence they flow! Nay, in all professions, how imperfect is man, unless illumined by the bright rays of religion, which like that glorious fountain of light, the sun, will enlighten all our paths.

Here though, it ought to be observed, that the religion which requires the stern rod of hierarchal jurisdiction for its support, does not always happen to be the true one; nor are those who are found in the gaudy trappings of sacerdotal array, always the imparters of sound doctrine: we have the *written word* of God to direct us in this important business; and we are endowed with understanding and conscience, to render us capable of judging of its meaning; without trusting too much to the some-times false glosses put upon particular passages, to serve the vile purposes of designing men.

Let me beg of you therefore to study with particular attention, that much neglected book the BIBLE; where energy of language, sublimity of sentiment, and the most exquisite beauties of oriental poetry, are among the least of its perfections*: from reading this book, and from contemplating the works of nature, we may learn that GOD is a *supreme*, *eternal*, *self-existent*, *necessary*, and *independent* Being; that he is also *invisible*, *immortal*, *incomprehensible*, *omnipotent*, *omniscient*, *omnipresent*, and *supremely good*. We may also thence deduce, that HE manages the world in wisdom and goodness, and governs it in justice, truth, and holiness; that "Not a sparrow falls to the "ground without HIM;" that "Even the hairs "of our head are all numbered;" and that all

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* The Bible, on account of the precepts it contains, and the consolations which may be derived from it, is above all praise. But before it can be of advantage to a reader, he ought to be convinced of the truth of revelation. Young persons should assent to the doctrines in this divine book; not, because they were born in a country where they have been *told* that they were true; nor, merely because they have been assented to, and defended by, very eminent men; but, because the evidences accompanying the various parts of the volume, have CONVINCED them, that it has GOD for its author, TRUTH for its matter, and SALVATION for its end. I cannot help adding, that when youth make these evidences the subject of their pursuit, they should bear in mind a precept, which ought always to accompany them when pursuing truth: namely, "As far as possible get rid of *old prejudices*, "and watch continually against *new ones*."

second causes derive their origin, permanency, and efficacy from HIM alone.

Since then, THE LORD GOD, is himself the source and perfection of all beauty and excellency, the Author of our existence, and the bountiful giver of all good gifts; we undoubtedly ought to love him with our whole hearts, and to serve him with all our powers; we ought to reverence his majesty and authority, and endeavour above all things to obtain his favour; we ought to devote ourselves entirely to his service, and make all our actions tend to the advancement of his glory. And as his mercy and goodness are unbounded, so should be our gratitude and praise.

JEHOVAH reigns: let ev'ry nation hear,
And at his footstool bow with holy fear;
Let heav'n's high arches echo with his name,
And the wide peopled earth his praise proclaim;
Then send it down to hell's deep gloom resounding,
Thro' all her caves in dreadful murmurs sounding.

He rules with wide and absolute command,
O'er the broad ocean and the stedfast land:
JEHOVAH reigns, unbounded and alone,
And all creation hangs beneath his throne:
He reigns alone; let no inferior nature
Usurp or share the throne of the Creator.

He saw the struggling beams of infant light
Shout thro' the massy gloom of ancient night;
His spirit hush'd the elemental strife,
And brooded o'er the kindling seeds of life:
Seasons and months began the long procession,
And measur'd o'er the year in bright succession.

The joyful sun sprung up th' ethereal way,
Strong as a giant, as a bridegroom gay;
And the pale moon diffus'd her shadowy light
Superiour o'er the dusky brow of night;
Ten thousand glittering lamps the skies adorning,
Numerous as dew-drops from the womb of morning.

Earth's blooming face with rising flow'rs he dress'd,
And spread a verdant mantle o'er her breast;
Then from the hollow of his hand he pours
The circling waters round her winding shores,
The new-born world in their cool arms embracing,
And with soft murmurs still her banks caressing.

At length she rose complete in finish'd pride,
All fair and spotless like a virgin bride:
Fresh with untarnish'd lustre as she stood,
Her MAKER bless'd his work, and call'd it good;
The morning stars with joyful acclamation,
Exulting sung, and hail'd the new creation.

Yet this fair world, the creature of a day,
Tho' built by God's right hand, must pass away;
And long oblivion creep o'er mortal things,
The fate of empires, and the pride of kings:
Eternal night shall veil their proudest story,
And drop the curtain o'er all human glory.

The sun himself, with weary clouds opprest,
Shall in his silent, dark pavilion rest;
His golden urn shall broke and useless lie,
Amidst the common ruins of the sky!
The stars rush headlong in the wild commotion,
And bathe their glittering foreheads in the ocean.

But fix'd, O God! for ever stands thy throne,
Jehovah reigns, a universe alone;
Th' eternal fire that feeds each vital flame,
Collected or diffus'd is still the same.
He dwells within his own unfathom'd essence,
And fills all space with his unbounded presence.

But oh! our highest notes the theme debase,
And silence is our least injurious praise:
Cease, cease your songs, the daring flight controul,
Revere him in the stillness of the soul;
With silent duty meekly bend before him,
And deep within your inmost hearts—adore him.

MRS. BARBAULD.

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APPENDIX;

CONTAINING SOME ADDITIONAL REMARKS ON

HEAT, COLD, AND LIGHT.

THERE is but little probability of our arriving at any great degree of accuracy in our opinions concerning these subjects, if in our reasonings upon them we only consider them separately; for there are several cases in which they have a dependence upon each other, which can only be traced out by considering them together: to answer this purpose the following pages are written.

As in the course of our discussion, the degrees of heat and cold will be spoken of, it appears necessary to premise a little with regard to the instrument by which they are usually (though not always) measured. This instrument is called a *thermometer:* to describe it with a nice particularity is not requisite, since more may be learnt from a five minute's examination of one, than could be gathered from a description which might fill half a dozen pages. In order that thermometers of different sizes may produce exactly the same conclusion in determining the heat or cold of bodies applied thereto, it is necessary to fix upon two certain points at some distance, of each of which we can judge by unvarying criterions. These in *Fahrenheit's Thermometer* (the one most generally used) are the *boiling* and *freezing points* of water: with regard to the former of these it should be recollected, as observed in the twenty-ninth Lesson, that the degree of heat at which water boils, is varied by the difference of the pressure of the atmosphere; the boiling heat is therefore taken at some certain degree of pressure; the degree now used is such as makes the mercury in a barometer stand at 29½ inches: as to the latter of these points, it does not appear to be a proper criterion, or, at least if it be, it has a wrong name affixed to it; for it is well known that, though fluids always *thaw* at the same degree of heat, yet the degree at which they *freeze* is liable to be varied with circumstances: it would therefore be better, if in future this latter point were laid aside, and instead thereof the *thawing* point made use of.

The different degrees of heat and cold are generally estimated by their distance either above or below the freezing point, those above may be denoted by the affirmative sign, those below by the negative one: though sometimes the words at length are used; and at others, the expressions *above or below nothing* are made use of; but this latter method seems somewhat absurd.

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Those who purchase thermometers ready made, should pay particular attention to the tube and corresponding divisions: it is frequently found that the tubes, instead of being cylindrical, are smallest in the middle, and widen gradually towards each end, like two conic frustums joined at their less bases. When this is the case, it is proper that the divisions, instead of being equal, should be longest in the middle, and decrease by regular gradations toward each end, so that the cavity in the tube shall contain the same quantity of fluid between every two divisions.

We now proceed to the more immediate objects of this Appendix, namely, *Heat*, *Cold*, and *Light*. The two latter of these will not be considered very attentively, only as they are connected with the former, which will be handled more at large.

Heat and Cold are to be considered either as particular sensations, or as the causes of powers which bodies possess of exciting those sensations. Thus, we say that we ourselves are hot or cold, and that the fire or ice which heats or cools us is likewise hot or cold: though the sensations we experience are certainly very different things from that which enables these bodies to excite them. It must be observed that the sensations of Heat and Cold are very fallacious ones, in so far as they are effected by the temperature of the body in which they are excited: for we may feel a substance hot when it is in the same circumstances in which we should feel it cool at another time. To elucidate this we may observe that when we have been accustomed to live in an atmosphere of betwixt + 60° and + 70°, if the Heat fall to + 60° we feel it cold: but, on the contrary, if we have lived in an atmosphere of between + 40° and + 50°, if the heat rise to + 60° we feel it very hot. Again, let two basons of water be taken, one heated only to + 35°, the other to + 110°, and put one hand into the one, the other into the other bason, for some time: if we then immerse both hands in water heated to + 60°, we shall with one hand feel this Cold, with the other Hot. Hence it may be reasonably inferred, that we cannot judge with precision of Heat or Cold by the sensations they excite in us.

In the next place, we are to consider Heat and Cold as the causes of powers which bodies possess of exciting particular sensations. As to *Cold,* it is seldom supposed to be either matter itself or a quality; it is more commonly looked upon as a deprivation of Heat, for the less the heat, found in a body, the greater the Cold, and *vice verſa*: there are particular cases in which Cold may be produced. 1. When some particular chemical attraction takes place, Cold is produced. 2. The conversion of solids into fluids, and of fluids into vapour, produces Cold, as is shewn by chemists. And 3. Cold may be produced by animal powers. It is not intended to relate experiments by which these may be proved: but the grand question which we most wish to determine,

termine, is, with respect to *Heat*, whether it be matter under some particular form, or only a quality? That our reasonings on this important subject may have the better effect, we must first reflect upon the various means of producing Heat. There are several ways by which Heat may be generated. 1. By means of the sun's rays. 2. By exciting vibrations in solids. 3. By the taking place of certain chemical attractions. 4. By conversion of vapours into fluids, and of fluids into solids. 5. By animal powers. 6. In volcanos.

And first, if a cold body be exposed to the rays of the sun, it will be heated.

It has been frequently conjectured that the sun was *fire*, burning and heating other bodies in like manner as a culinary fire: but the celebrated Dr. *Fordyce* has asserted, that the sun is probably not at all hot in itself; neither are the solar rays hot, but have only a power of producing Heat on being applied to other bodies. An opinion very little different from this is also entertained by Dr. *William Herschel*, and supported with the authority of demonstration. As a farther consideration of this subject may tend to correct our notions concerning *Light*, it is here attempted.

It is a constant rule, with regard to hot bodies, that they heat all colder bodies which are brought near them. Though it must be allowed (as will be hereafter seen) that some bodies will receive Heat with more readiness than others: however, this will not easily form an objection to what immediately follows.

Now, if we take a large burning glass and hold a piece of iron in its focus, such heat will be produced as to melt the iron. But the glass through which all the rays passed is scarcely heated at all: and when they fell on the iron they were no hotter than water when it is poured on vitriolic acid. But if we place water which is perfectly transparent in the focus, no heat will be produced: nay, if spirits of wine were placed in the focus they would scarcely be heated. But the same Heat which melts iron, would more than suffice to make water boil: from this experiment then, without advancing farther arguments, it appears that the rays in themselves have no Heat; and there is no reason to suppose that the sun is hotter than the earth we inhabit.

It is a question that has been much agitated, whether the solar rays be matter, or only an arrangement of matter; but their materiality is now pretty generally agreed to; but a question which has not yet been answered satisfactorily, is, "If "Light be matter, what becomes of it?" Perhaps there is a distinction between Light and the solar rays, which has not yet been properly attended to.

The sun's rays heat bodies only when they are *bent* or *destroyed*. (The term *absorbed* does not in our opinion exactly answer the purpose.) Hence they do not heat water if perfectly transparent; neither, do they heat the air above the clouds: at least, as very little bending takes place in these cases, the Heat is so trifling as to be scarcely worth mentioning. The upper regions of the air then, are extremely cold, though exposed to the direct action of the sun.

When a ray of Light is reflected, it does not *touch* the body reflecting it; but is thrown back before it arrives at the surface: therefore the more white bodies are, or the more highly they are polished, the less they are heated, because they reflect more of the rays: and when a body is perfectly white it reflects all the light, and is not heated at all.

Bodies in proportion as they deviate from white, destroy the more solar rays, and a perfectly black body would destroy them all: hence bodies are more heated, *cæt. par.* as they are darker coloured by this cause of Heat.

When a body is rough, as if we make a piece of glass so (which may have no colour) it destroys part of the rays, or at least, suffers them to approach so near its surface before it reflects them, that they cause it to be heated.

Thus far our reasonings induce us to suppose that *Heat* is a *quality*: but Heat, as a quality, cannot exist without a substance to exist in. So that, if it were possible to produce a *perfect vacuum*, there could be no Heat therein. This also leads us to conclude, that the denser a body is, the more Heat may be therein produced; other circumstances being the same.

Heat, it is affirmed, can only be produced by the solar rays at the surfaces of bodies: consequently the interiour parts can only be heated by communication. And if we keep in mind that heat is more readily transmitted, communicated, and received, by some bodies than others; it will then appear that, as a body receives Heat with more facility, it will be the more heated by the sun's rays: as a piece of iron will be more heated than a piece of wood.

We have seen then;—that the solar rays are not hot in themselves:—that they produce Heat only when they are bent or destroyed:—that therefore they do not heat transparent bodies, nor do they heat in passing through them, but only at their entrance and passing out again.

It is evident, since the rays of the sun have a power of producing Heat, that they will heat a body more, the greater the quantity is that falls on it. From this principle, combined with some particular circumstances, arises the different Heat and Cold of the seasons, and of different parts of the earth. For instance, the Heat about the equator has been known to arise to + 110°: and, it is said, that the Cold in Siberia has been as low as — 160°; but the truth of this may be doubted, for I do not see how so great a degree of Cold can be precisely measured.

The heat produced by the solar rays is increased also by reflection of them: if they be frequently reflected, a greater Heat is produced than even if they be all destroyed. Thus we find that if we receive them into a box so constructed as to reflect them frequently from side to side, more Heat will be produced than in a box made black, so as to destroy them almost all. Hence, in vallies, even in temperate climates, where the rays are reflected frequently, very great Heat is also produced.

The different distances of the planets from the sun, it is imagined, makes a great difference in the number of the rays and in the momentum with which they fall on them. So that it has been thought that Mercury is exceedingly hot, and Georgium Sidus cold beyond conception: but since the Heat produced in bodies depends on their disposition to receive it, the several planets may be so composed as to have but a very trifling difference in the Heat produced by the solar rays. Hence then, what has been hitherto said concerning the Heat of the planets, as calculated on the supposition of the sun being the source of Heat, may be called in question: and, perhaps the Newtonian opinion concerning comets (recited in the astronomical part of this work) may in time be entirely abandoned, and some later hypothesis generally received.

Thus much for the first method of producing Heat.

The next method of producing heat is by exciting vibration in solids. Whether fluids can be thus heated we don't know: there is no clear instance of heat being produced by their vibration. We may excite vibration in solids, by friction or by collision: if we rub together or strike two bodies, if they have any elasticity they will vibrate. The rougher bodies are which are rubbed together, the greater vibration is produced, and therefore the greater heat. The vibration is also, *cæt. par.* in proportion to the elasticity of bodies.

In *Count Rumford's* ninth Essay, which is an enquiry into the source of the heat that is excited by friction, many interesting experiments are related. From these experiments it appears, that sufficient heat was produced by the friction of two metallic surfaces (when the access of atmospherical air was entirely prevented) to make water actually boil. It appeared that a very considerable quantity of heat was excited by the friction, and given off in a constant stream, *in all directions*, without interruption or intermission, and without any signs of diminution or exhaustion.

This ingenious philosopher, when reasoning on these experiments, gives satisfactory reasons to prove that the heat could not be furnished either by the air, or by the water which surrounded the machinery. And, considering that the source of the heat generated in these experiments, appeared evidently to be *inexhaustible*, he naturally concluded, that *heat* could not be *matter*: for, says he, "It "is hardly necessary to add, that any thing which "any *insulated* body, or system of bodies, can "continue to furnish *without limitation, cannot* "*possibly be a material substance.*"

Another method of producing heat is by the taking place of chemical attractions. Every chemical attraction as far as we know, in taking place, produces either heat or cold: whether it be simple combination, elective attraction, or compound elective attraction. Some of the chemical attractions, are attended, besides the production of heat, with another striking phænomenon, namely, the producing of *light*. For instance, this is produced by the combination of resp. air with phlogiston: and other instances might be adduced; this strikes out an interesting subject of philosophical inquiry.

The fourth and fifth methods of producing heat might be descanted upon very copiously; but perhaps this would have but little tendency towards determining what heat is.

Lastly, Heat is produced in volcanos. This has commonly been supposed to be by the burning of fuel. But it is evident that it cannot be *produced* by this cause, or by any other known means of the production of heat. The burning of fuel, it is known, destroys a proportionate quantity of air: to produce a very great degree of heat requires still more to be applied than is naturally combined with phlogiston. Now the whole island *Santalina* is a mass of iron ore very difficult of fusion, which was fused and thrown up from the bottom of the sea in the midst betwixt two shores by this heat; where no air could therefore possibly come. And if it could, it would have required more in quantity than would have exhausted the whole atmosphere, to animate fuel enough to have produced the heat. In Friesland, some time ago, there was a tract of country 100 miles across, the whole of which (with men, animals, trees, and whatever was on it) was melted into one common mass. This heat then, cannot be produced by the burning of fuel; much less can it be by the decomposition of pyrites, which is indeed the burning of sulphur. And by what means such intense heat is produced, we are at a loss to determine.

Having spoken of the various methods of producing heat, we must next observe, that bodies may be heated by communication. And several experiments might be described to shew, that some bodies will both communicate and receive heat more readily than others. It is the same with respect to cold as to heat: for those bodies which receive heat most readily, most readily part with it, and if they do this, they must also suffer it to pass through them (speaking of it as though it were a body) from one substance to another, or conduct it most readily, and *vice verſa*.

Iron is a good *conductor* of heat; on the contrary, wood is one of the best *non-conductors* of heat known. That the former is a conductor, and the latter a non-conductor of heat, is evident from the following simple experiment: if you take a nail or a small piece of iron, and hold in the flame of a fire or candle, it will speedily become so hot all over, as to oblige you to relinquish your hold; but if you take a small piece of wood and hold in the flame, you may keep hold of it till it is nearly all consumed by the fire, without being incommoded by the heat of the wood. Hence heat passes with ease in iron, and with difficulty in wood.

From the results of various experiments, *Count Rumford*[*] concludes that *water*, *oil*, *mercury*,

and

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[*] In the Essays of this philosopher, very ingenious principles are applied to practical uses in the *great art of living*. That my young readers may have an idea of the advantages which may arise, from applying philosophical principles to such purposes, I present them with the following extracts:

In Essay VI. the Count says,—" Among all the various sub-
" stances of which coverings may be formed for confining Heat,
" none can be applied with greater advantage than atmospheric
" air. It is what Nature employs for that purpose; and we
" cannot do better than imitate her.

" The warmth of the wool and fur of beasts, and of the fea-
" thers of birds, is undoubtedly owing to the air in their inter-
" stices; which air, being ſtrongly attracted by these substances,
" is confined, and forms a barrier, which not only prevents the

cold

and *air*, are *non-conductors* of heat: indeed he thinks it essential to all fluids, that they should be *non-conductors* of heat; or that all interchange and communication

" cold winds from approaching the body of the animal, but " which opposes an almost insurmountable obstacle to the escape " of the Heat of the animal into the atmosphere. And in the " same manner, the air in snow serves to preserve the Heat of the " earth in winter. The warmth of all kinds of artificial cloth- " ing may be shewn to depend on the same cause; and were " this circumstance more generally known, and more attended " to, very important improvements in the management of Heat " could not fail to result from it. A great part of our lives is " spent in guarding against the extremes of Heat and of Cold, " and in operations in which the use of Fire is indispensible; and " yet how little progress has been made in that most useful and " most important of the Arts—the management of Heat!

" Double windows have been in use many years in most of the " northern parts of Europe, and their great utility, in rendering " the houses furnished with them warm and comfortable in " winter, is universally acknowledged,—but I have never heard " that any body has thought of employing them in hot countries " to keep their apartments cool in summer;—yet how easy and " natural is this application of so simple and so useful an in- " vention!—If a double window can prevent the Heat which is " *in* a room from passing *out of it*, one would imagine it would " require no great effort of genius to discover that it would be " equally efficacious for preventing the Heat *without* from com- " ing *in*. But natural as this conclusion may appear, I believe it " has never yet occurred to any body; at leaſt, I am quite cer- " tain that I have never seen a double window, either in Italy, or " in any other hot country, I have had occaſion to visit."

A little

communication of heat *among their particles*, or from one of them to the other, is absolutely impossible. Glass, when rendered of a loose texture, conducts heat with very great difficulty. Insomuch that the lava of a volcano has, sixteen years after an eruption, been found *red hot* a foot under the surface of such glass, though this was quite cool. This circumstance might very probably give the hint for the assertion (paradoxical as it may seem without proper deliberation) that it would be no difficult matter to convey an iron ball *red hot* from London to Lincoln: to perform this, it must be inclosed in pumice stone, which is very porous glass, formed by volcanos, and then covered over with fur. It is also easy, by covering a room with fire, to preserve the air in it of the same temperature, without bringing any thing into it either hot or cold, for a very great length of time.

As to the effects produced by Heat; it is known to expand bodies, and some late chemists affirm, that it tends to diminish every attraction we are acquainted with: they produce experiments to evince

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A little farther on, he says,—" There is no *communication* of " Heat *between one particle of air and another particle of air*. " From hence it follows, that though air may, and undoubtedly " does, *carry off* Heat, and *tranſport it* from one place, or from " one body to another, yet a mass of air in a quiescent state, or " with all its particles at rest, *could it remain in that state*, would " be totally impervious to Heat; or such a mass of air would be " a *perfect non-conductor*."

that Heat diminishes the attraction—of gravitation, —of cohesion,—of magnetism,—of electricity, and chemical attractions. But though it may be the case in particular instances, it will be better not to be too sanguine in imagining that such effects will take place *univerſally*. The assertion may be disputed with regard to the attraction of gravitation, and that of electricity. However, those who allow that Heat universally diminishes the electrical attraction, will strongly contend in support of their opinion, because they may thereby explain with facility the reason of the frequency of thunder-storms in summer.

From a review of what has been here advanced, we shall find that there are few, or, perhaps, we may confidently say, no appearances, but what will admit of as easy an explanation, by conjecturing that Heat is a quality, as by supposing that it is a substance. Nay, some of the phænomena, particularly those which attend the production of Heat by friction, or vibration in solids, will (as must appear from what has been previously observed) induce us to incline more to the former hypothesis than to the latter. Besides, whether Heat be a substance, or a quality, it is manifest, that it may be created and annihilated. Now, we have no idea of matter being created and annihilated by any natural cause, (for under all its variety of forms, matter is matter still;) then what kind of a substance must heat be, to be produced and destroyed by so many causes?

Why, truly, nobody can tell: for it must have a property which matter has not. Heat must then be a *quality*: for qualities we know can easily be created and annihilated. And if Heat be a quality it must have matter to exist in, so that if we apply any of the causes producing Heat, no Heat is produced unless there be some matter to receive it. This therefore is the result of our enquiries into the nature of Heat.

We have also seen, that *Light* may be produced by particular means, the solar rays for instance; it may likewise be destroyed, as has been previously shewn. The method of reasoning just applied to Heat, may with equal propriety be used here: and this will induce us to conclude that *Light*, instead of being a *fluid per ſe*, as has been sometimes conjectured, is a *quality*, and can no more exist independently of matter than Heat can.

Whether these conclusions may be safely relied on, is not for us to determine: the great mysterious BEING who made and governs the universe, has set a part only of the chain of causes in our view; and we find that as HE himself is too high for our comprehension, so HIS more immediate instruments are also involved in an obscurity that our feeble endeavours are not able to dissipate. However, as Mr. *Maclaurin* has observed,—" From what we
" are able to understand of nature, we may enter-
" tain the greater expectations of what will be dis-

" covered to us, if ever we shall be allowed to penetrate to the First Cause himself, and see the
" whole scheme of his works as they are really
" derived from Him, when our imperfect philosophy shall be completed."

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FINIS.

EXPLANATION OF THE PLATE.

THE Plate which is given as a Frontispiece, is a projection of the northern and southern CELESTIAL HEMISPHERES on the plane of the *Equator.* The center of the first projection is the *North pole* of the Equator, around which are described two circles; the smaller is the *Arctic circle*, the larger, the *Tropic of Cancer:* a little above the center of the first projection is the *North pole of the Ecliptic*, where all the *Circles of latitude* drawn through every tenth degree of each *Sign of the Zodiac*, meet and intersect each other. The center of the second projection is the *South pole* of the Equator; the first of the two circles, which are described about it, is the *Antarctic circle*, the other is the *Tropic of Capricorn:* a little below the center of the second projection is the *South pole of the Ecliptic*, where all the Circles of Latitude meet and intersect, as in the northern Hemisphere. From the Poles of the Ecliptic as centers, the *Circles of Longitude* are drawn at every 10th degree: that circle which is described at 90° from each pole of the Ecliptic, is the *Ecliptic* itself; of this, half appears in the one projection, and half in the other; it intersects the Equator in the first points of Aries (♈) and Libra (♎). The diameter of each projection which crosses it from top to bottom, is called the *Solstitial Colure*, because it passes through the Solstitial points, *Cancer* (♋) and *Capricorn* (♑): the diameter that crosses each projection from right to left denotes the *Equinoctial Colure*, so called because it passes through the Equinoctial points, *Aries* and *Libra*. These four points of the Ecliptic which are crossed by the Colures, are called *Cardinal points*, and when the sun enters one or other of these points, one of the four *Seasons* of the year commences.

The Stars are given in this plate as they appear on the surface of the *Celestial Globe*, with this difference, that the figures of the Constellations are omitted, as they would only tend to create confusion when the Hemispheres are projected on so small a scale. The Stars, as was observed in the fifteenth Lesson, are usually divided into six classes, according to their apparent magnitudes: this distinction of size it has been attempted to preserve as nearly as could be consistently with the size of the projection. It is hoped that in many instances the stars of different magnitudes may be reckoned without much difficulty: Thus, in *Ursa Minor*, or the *Less Bear*, it is easy to reckon 2 stars of the second, 1 of the third, 3 of the fourth, 1 of the fifth, and 3 of the ſixth magnitude. Again, in *Canicula* or the *Little dog*, you may discover 10 stars, whereof 1 called *Procyon* is of the first magnitude.

CORRIGENDA.

At page 162. When speaking of the different sizes of the *Rainbow*, it ought to have been observed, that at all those places and times when the altitude of the sun is more than 42°, no primary Rainbow can appear; and when his altitude exceeds 54¼°, no secondary Bow or Watergall can appear. To learn the reason of this, the young reader may consult Dr. *Enfield*'s *Philosophical Institutes*, Dr. *Hutton*'s *Dictionary*, or Mr. *Martin*'s *Philosophia Britannica*.

Page 250. Last line, *for* liable *read* likely.

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